

The AMSAT[®] Journal

Editor-in-Chief:
Ed Long, WA4SWJ

Editorial Staff:
John Bubbers, W1GYD
Bill Hook, W3QBC

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Dick Daniels, W4PUJ, views a PCSat model at the new James S. McDonnell Space Hangar at the National Air and Space Museum's Udvar-Hazy Center near Dulles airport.



Photo by W3PK

Also: Read about the AMSAT Symposium, AMSAT's new officers and much more in this issue.

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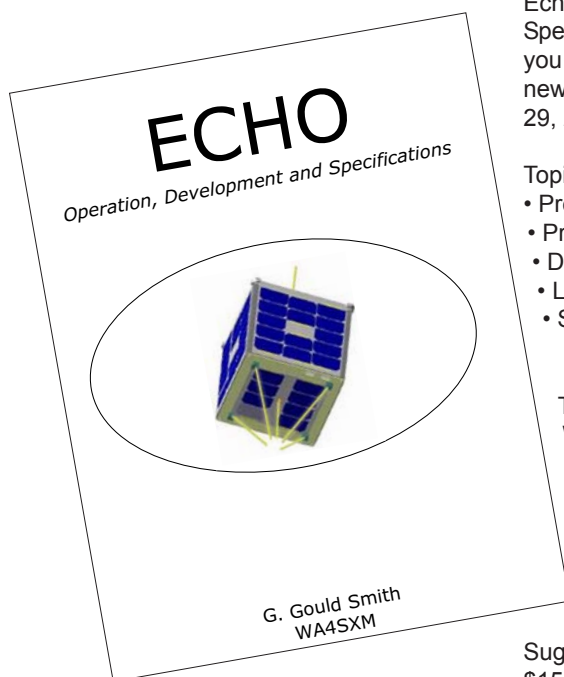
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AMSAT is a non-profit volunteer organization which designs, builds and operates experimental satellites and promotes space education. We work in partnership with government, industry, educational institutions and fellow Amateur Radio societies. We encourage technical and scientific innovation, and promote the training and development of skilled satellite and ground system designers and operators.

AMSAT's Vision

Our Vision is to deploy high earth orbit satellite systems that offer daily coverage by 2009 and continuous coverage by 2012. AMSAT will continue active participation in human space missions and support a stream of LEO satellites developed in cooperation with the educational community and other amateur satellite groups.





Radio Amateur Satellite Corporation (AMSAT-NA)
850 Sligo Ave., Silver Spring, MD 20910-4703
Telephone: 301-589-6062 – Toll Free: 888-322-6728
Facsimile: 301-608-3410

AMSAT-NA Club Callsign - W3ZM
AMSAT-NA website: <http://www.amsat.org>

The AMSAT Journal Staff

Editor-in-Chief: Ed Long, WA4SWJ
(wa4swj@amsat.org)

Circulation: Martha Saragovitz
(martha@amsat.org)

Editorial Staff:
John Bubbers, W1GYD; Bill Hook, W3QBC

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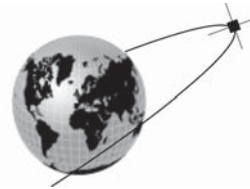
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APOGEE VIEW

by Rick Hambly, W2GPS • w2gps@amsat.org



This is my first Apogee View column as your president. I feel honored by your trust and humbled to follow in the footsteps of AMSAT's past presidents. I accept this opportunity to serve because I believe AMSAT is at a crossroads in its history. We will need a clear vision of our future backed up with an effective leadership team to reach our true potential. Fortunately, our immediate past president Robin Haighton, VE3FRH, has provided me with a solid basis for this effort having led AMSAT during the development and launch of AO-51, our first new satellite in over a decade, and during the development of AMSAT's new Mission and Vision statements.

I begin by telling you about the planning that I and AMSAT's board members, officers and senior advisors have worked on over the past year that has been implemented with the approval of the Board at their October 2004 meeting. In later columns I will discuss specific activities and how all of this will affect each of you, AMSAT's loyal members. The planning process falls into two broad categories, Strategic and Tactical.

Strategic Planning

In February 2004 AMSAT began a new round of strategic planning. This time the planning was to be done by the board members assisted by a few officers and advisors and led by an outside facilitator. The goal was to strip away the façade and take a penetrating and critical look at AMSAT so that we could express what AMSAT should be. We then developed a list of actions that we would need to address to achieve a positive future. To do this we went through an intense three step process. First was a discovery process, the "State Of The World." Second was the decision stage, "AMSAT in 45 Seconds." Finally there were the "Ten Stakeholder Questions" to be answered. These questions are "Who are you? What do you do? Who will care? Why will they care? How many will care? How do you get to those who do? How will you "make" money? How are you unique and how will you defend your space? Do you have the team to pull it off? How much money do you need and where does it take you?"

The results of this process are the Mission and Vision statements that are now our guiding statements and a set of action items. The board members and senior officers have been meeting in teleconferences every two weeks since February to work on the action items. At the present rate we should get through the list in another year. As a result

of this process your board and officers are much more actively engaged in planning for AMSAT's future than at any time in AMSAT's history.

Tactical Planning

It is the responsibility of AMSAT's officers to implement the Board's strategic planning directives. In October 2004 we changed AMSAT's executive organization to better reflect the new Mission and Vision statements. Instead of having many Vice Presidents all reporting to the President, we now have teams of people each dedicated to a specific area of responsibility and led by an Officer of AMSAT. Together, these Officers (team leaders) form another team, the Executive team. The emphasis here is on teamwork and cooperation, not hierarchical reporting responsibilities.

The new list of corporate officers and members of the executive team are President (Richard Hambly, W2GPS), Executive VP (Lee McLamb, KU4OS), VP Operations (Mike Kingery, KE4AZN), VP Engineering (Stan Wood, WA4NFY), Treasurer (Gunther Meisse, W8GSM), Corporate Secretary (Steve Diggs, W4EPI), Manager (Martha Saragovitz), VP Marketing and User Services (Barry Baines, WD4ASW), and VP Human Spaceflight (Frank Bauer, KA3HDO). Notable in this new alignment of responsibilities are the two new Board appointed officer positions: VP Marketing and User Services and VP Human Spaceflight. The Executive VP leads a team with responsibilities for educational, industrial, governmental and international relations.

The VP Marketing and User Services leads a team that consolidates responsibilities to achieve a synergy of purpose among them. These include electronic communications, contests and awards, AMSAT News Service, sales, *The AMSAT Journal*, Field Operations and the Web site.

The VP Human Spaceflight has a team that crosses organizational boundaries between AMSAT, ARRL and NASA. While this team remains the same as it was, the elevation of this position to that of an Officer, with membership on the executive team, is an indication of the importance AMSAT places in our involvement in the human spaceflight program. AMSAT plans to be there when humans again travel beyond the low orbit

Apogee View is continued on page 5



What is AMSAT®?

AMSAT members are a worldwide group of enthusiastic individuals designing, building and operating Amateur Radio satellites as part of our program of space science education.

The Radio Amateur Satellite Corporation (AMSAT or AMSAT-NA) is a non-profit scientific and educational organization chartered in Washington, DC, in 1969. Since then, AMSAT and colleague organizations around the world have built over 50 ham radio satellites. Fifteen of these satellites continue in operation.

Joining AMSAT supports our current projects: Eagle, AMSAT-OSCAR-E (Echo) and ARISS. Eagle is a high orbit DX capable satellite planned for a 2007 launch. Echo is a low orbit FM and digital bird you will be able to use with simple equipment, planned for launch in 2004. And ARISS is our program on the International Space Station. You will keep up to date on the world of Amateur Radio satellites with 6 issues of the AMSAT Journal every year.



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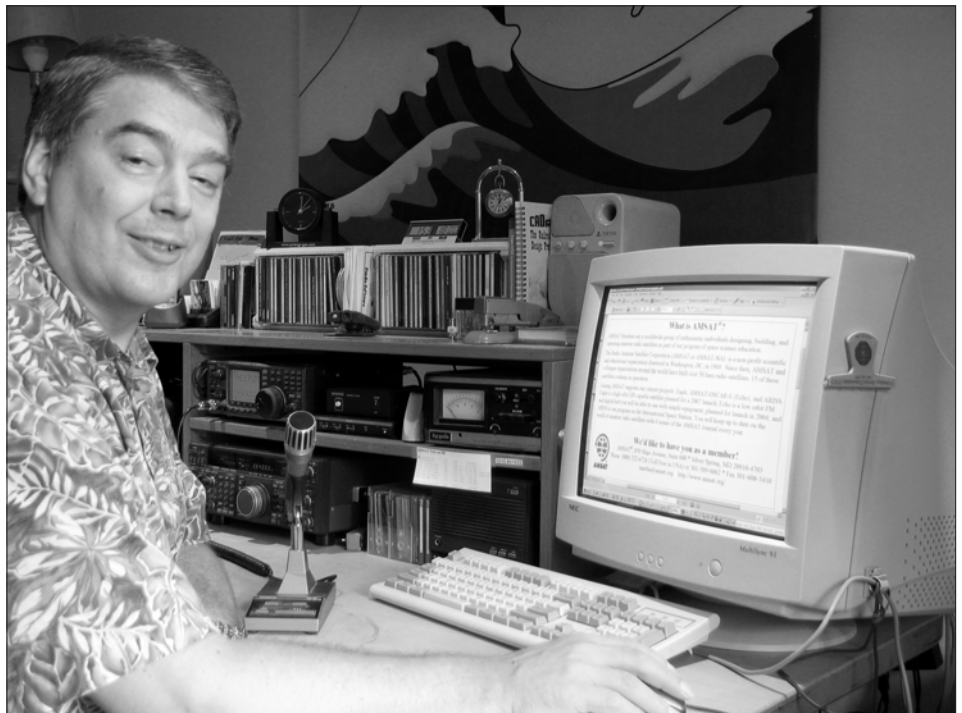
Do you send QSL cards for satellite contacts? You can help AMSAT by inserting the form above describing AMSAT and providing membership information when you send your QSL's. Put one of these inserts in with every QSL mailing and will help other hams find out about AMSAT and you will help AMSAT build new satellites by helping to add new members.

Included at the amsat.org Web site are forms for single sided printing ... just print, cut, fold and mail. You can also find forms for double sided printing if you prefer.

You can find the AMSAT QSL inserts online at:

<http://www.amsat.org/amsat/amsat-na/membership.html>

Rick Hambly (right), W2GPS, AMSAT President, is shown viewing the AMSAT QSL Insert. Add one to your QSL's and encourage your fellow hams to join AMSAT.



AMSAT- President's Report 2004

To: All members of AMSAT-NA

From: Robin Haighton, VE3FRH –
Outgoing President

This year's report covers a little more than just 2004 as I would like it to reflect the previous 3 years and to relate some of the accomplishments as well as the problems encountered over the 4-year span.

In 2000 when we met in Portland, Maine, the Board elected me as your President. I entered the position in the full belief that we were about to have a glorious period of time for AMSAT and for the amateur satellite fraternity.

The launch of P3D was absolutely exemplary. Arianne 507 did a superb job of launching the satellite from Kouru, French Guiana. The orbital projections could not have been more perfect under any circumstances. While we did lose the 70 cm transmitter during the launch, this was only a minor inconvenience at that time. A few weeks later we met with a bigger problem from which we have learned a great deal. Now P3D (AO-40) is no longer an active satellite and we can only hope that one day the main batteries on board will present a high enough impedance to allow the auxiliary batteries to charge – if that is the problem. However, many of us were able to carry out good U/S and L/S communications through AO-40 from May 2001 for over two years.

Following our major problem with AO-40 and somewhat less than a year after its launch, the whole world was awakened to the terrorism threat by the events of 9/11. It quickly became obvious that it was going to be very difficult to raise funds for another satellite unless an innovative program was introduced. Thus, the President's Club was formally announced at our October meeting of that year. This has, I believe, been one of our major successes of the past few years. Look in your July/August 2004 *AMSAT Journal* and see the number of Gold, Silver, Bronze and Core members we have. There is also one Platinum member.

However, as we were quoted a massive financial figure to put Eagle into a GTO orbit; the Board considered that it would be far more effective to have Echo (AO-51) a low orbit satellite for which we could raise funds in a reasonable time. Of course ENRON, World Com, Arthur Anderson and a general decline in the economy of the USA further compounded the fund raising problems initiated by 9/11.

That meant the move to Echo became fully financially justified even though there was

a strong body of opinion within AMSAT-NA that wanted a GTO satellite.

In the summer of 2003, Bill Tynan and Dick Daniels, two long serving members of the BoD did not run for re-election. This permitted Rick Hambly and Gunther Meisse to become members of the Board of Directors. In addition, with the resignation of Keith Baker from the Board, Lou McFadin became a new member. This "shake up" of the Board has resulted in new thinking as to the future of AMSAT and an updated approach to fund raising. Gunther has organized a survey of the membership, which I am sure will be a topic of conversation for a long time to come. Rick has undertaken to lead a strategic planning exercise to modernize our structure. These moves have had both the Board in general and my full support; so I am pleased to advise you that there will be more to come!

AMSAT must continue to respond to the needs of the membership – or there will not be an AMSAT. While these administrative efforts were taking place, Echo was being finally integrated and tested. Chuck Green was our representative at the launch site in Kazakhstan and I leave it to Chuck to provide you with his comments. June 29 was lift off day and finally we were back in Space with an AMSAT-NA working satellite.

I should add that several AMSAT-NA people have, for the past two years or so, been working closely with AMSAT-DL on the P3E satellite, which will effectively replace AO-40 and be a predecessor to P5A the Mars Mission being built in Germany. Several critical items including the Can-Bus and the IHU-3 have been worked on by our members for these satellites and will also be utilized in Eagle.

The year 2004 has been a year of accomplishments, including the new web site, Echo, the start of the new strategic plan and the definition of the Eagle mission. I feel that the next year will even more accomplishment filled with better defined benefits for members among other things together with progress on Eagle.

For an overview of things to come, I turn the meeting over to your new President, Rick Hambly, W2GPS.

73,
Robin Haighton, VE3FRH
Immediate Past President



Apogee View continued from page 3

of the International Space Station, perhaps to the Moon or Mars.

The other teams are organized around responsibilities that are similar to the way they were in the past, although they are already making many improvements in response to our new strategic planning process.

AMSAT's Board, aided by their executive team and other advisors, continues to work on strategic planning. This activity has resulted in new Mission and Vision statements and a new executive organizational structure based on teams and teamwork. Continuing strategic planning efforts will result in more important results in the near future. Your leadership is committed to a bright future for AMSAT and its membership.

73,
Richard M. Hambly, W2GPS
President

SKN - 2005



Straight Key Night on OSCAR 2005

Once again, AMSAT North America is pleased to sponsor Straight Key Night (SKN) on OSCAR for the enjoyment by all radio amateurs. OSCAR SKN 2005 will run for 24 hours, 0000-2400 UTC, on 1 January 2005. It's very simple: no rules, no scoring, and no need to send in a log. Just operate CW through any OSCAR satellite using a straight hand key working as many other SKN participants as you can. Contacts via the moon (OSCAR Zero) count too.

As in past years, all participants are requested to nominate one of the operators they worked for "Best Fist" recognition. Your nominee need not have the best fist of those you heard, just of those you worked. Please send all nominations to me at w2rs@amsat.org. A list of those nominated will be published via the AMSAT News Service in early February and in *The AMSAT Journal*.

73,
Ray Soifer, W2RS
for AMSAT NA



Technical, Security and Regulatory Considerations When Planning the Use of Simplex Telecommand Systems in Small Satellites

Jan A. King¹, VK4GEY/W3GEY
Radio Amateur Satellite Corp. (AMSAT)

INTRODUCTION

The availability of low cost transmitter/receiver hardware in SIMPLEX operation^{2,3} has come to the attention of many of the universities developing small satellite systems. The concept of using this telecommunications hardware, upgraded for space use, is attractive and has many advantages for low-cost systems. Among the advantages are:

- A potential reduction in the size, mass and average power of the telecommunications hardware on board the spacecraft
- The economy of using only a single frequency for both transmit and receive
- The potential of using a companion radio (a carbon copy of the spacecraft version, but with bigger antennas) for the satellite ground station
- The need for only one simple antenna on the spacecraft
- The potential to operate a common network of satellites (constellation) using half duplex, space-to-space relay techniques

These advantages are compelling. However, one must consider these advantages in the light of other important considerations. It is my intent here to outline the overall "cost" of using simplex telecommunications equipment on board a small satellite system. The recommendations made (and insights provided) are based on many years of AMSAT experience in operating small satellite systems. There are network reliability, satellite security and regulatory factors that should be considered before final choices for the telecommunications equipment and method of operation are determined for any particular satellite system.

TECHNICAL CONSIDERATIONS

There are several purely technical factors that should be considered before a satellite project chooses to use a *simplex* telecom system. Some of the issues may be well understood, however, there are others that may be less obvious.

The Doppler Effect

The apparent shift in frequency caused by the velocity of a satellite relative to an observer is proportional to both the absolute frequency of the transmitter and the

satellite's velocity. It is worth noting, by the way, that not only the carrier frequency is shifted but also, the modulating frequency is Doppler-shifted. The appropriate relationship is:

$$f' = f_o \left(1 \pm \frac{v}{c} \right)$$

where:

f' = Doppler-shifted carrier or modulation frequency

f_o = nominal carrier frequency or mean modulation frequency

v = satellite velocity relative to the observer (It is noted that this is normally a vector quantity). The use of the " $\pm$ " here is to denote the two extreme Doppler shifted values.

c = velocity of the carrier wave = speed of light

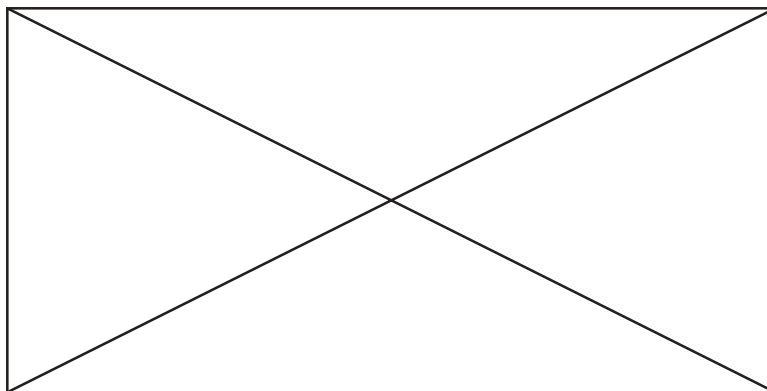
It's important to get a feel for the magnitude of the Doppler shift in frequency that occurs between a ground station and a satellite. Take, as an example, a satellite in a circular orbit at 600 km altitude. To first order, the speed of the satellite is constant and equal to 7,558 m/s. If the satellite had a transmitter operating at exactly 100 MHz, the Doppler-shifted frequency as the satellite moves directly toward the ground station observer would be 100.002521 MHz. As the satellite moves directly away from the observing ground station the observed transmitter frequency is 99.997478 MHz. It can be seen, with a little thought, that the worst-case Doppler shift for a direct overhead pass in this example satellite would be ± 2521 Hz or a total shift of 5042 Hz.

Continuing with this example, the following table gives the worst case or largest value of Doppler shift that can occur in frequency bands commonly in use within the amateur-satellite service. The same orbit is assumed.

As can be seen, the maximum Doppler shift is small at low frequencies, such as within the 29 MHz band. The frequency shift experienced during a typical pass (perhaps amounting to only 70-80% of the maximum shift) is on the order of one kilohertz. This is a small fraction of the modulation bandwidth of most contemporary digital radio systems. However, if the use of the most popular band at 435-438 MHz is contemplated, the Doppler shift over a pass is typically as large as 18 kHz (note that it could be as large as 22 kHz) for LEO missions. When popular modulation methods for data transmission such as 9600 bps "G3RUH FSK" are used, the Doppler shift in frequency is approximately equal to the entire channel bandwidth and the bandwidth of the ground station receiver filter. This requires the radio or the operator to retune the receiver several times during a pass to keep the signal centered in the passband. If higher frequencies such as 2400 MHz are to be used, the Doppler shift and time rate of change of frequency caused by Doppler are large indeed. The change in frequency can be as large as 120 kHz, which is approximately six times the bandwidth occupied by this same type of data system. The time rate of change at the center of the pass (time of closest approach or TCA) is on the order of 1.0 kHz/sec.

This then brings up the first set of issues that must be dealt with if a simplex radio system is to be employed:

Table 1



- a) It is important that both the satellite transmitter/receiver system and the ground station system (whether it is a companion radio or not) are capable of handling the Doppler shift in frequency. Most terrestrial radios are not capable of adjusting –for Doppler shift since satellite systems and very high-speed aircraft are about the only vehicles that travel fast enough to require this capability. The vendor of the transceiver may not have contemplated this application. One means of dealing with this problem is to increase the bandwidth of the receiver filters on both ends of the link so that even with the Doppler shift, the modulation bandwidth of the transmitted signal still stays within the receiver filter bandwidth. This has a penalty associated with it. The extra bandwidth adds thermal noise ($P_n = kTB$) and this noise reduces the S/N (or E_b/N_t) of received signal.
- b) If the satellite transmitter is normally OFF and is commanded ON, there must be a means (automatic or manual) for adjusting the receiver center frequency to account for the change in frequency since the last transmission. To the receiver this will appear as a “jump” in frequency between two ON periods. If the transmitter is commanded ON only once during a pass then the Doppler shift introduces an uncertainty in terms of where the center frequency (f^*) will be located at any given instant in time when the transmitter comes ON.
- c) Some receiver systems are required to be “locked” to a carrier (usually, but not always located in the center of the modulation spectrum) prior to demodulation of data. Such a system is known as a *coherent* system. These systems must be able to acquire and track a changing carrier frequency. If the simplex system contemplated for use employs coherent technology, it should be verified that the frequency tracking range of the carrier acquisition and tracking loop is large enough to accommodate the maximum Doppler shift in frequency. It would be very useful if the receiver could automatically acquire the carrier by using a sweeping loop or equivalent technology.

It's important to realize that when a simplex system is used, the satellite receiver will experience the same Doppler shift on the command uplink. Any correction made to the downlink frequency must be made to the uplink as well, and in the OPPOSITE direction. In this situation, the use of simplex can be helpful as the measured downlink

Doppler frequency shift can be applied as a correction on the command uplink.

Energy Management

For most very small satellite systems, energy management is a first-order system design parameter. To maintain a positive energy budget, which will allow the spacecraft battery to remain fully charged, it may be necessary to cycle the transmitter ON and OFF. The RF transistors used for the power amplifier chain of a spacecraft transmitter are critical devices in many ways. The transistors or integrated circuits employed in that application should have the highest DC-to-RF conversion efficiency possible. At VHF and UHF frequencies, these devices could have efficiencies as high as 85% (given the current state of technology). However, RF devices employed in most commercial radio products operating in this frequency range and designed for terrestrial use do not achieve this level of efficiency. Values in the 30% range are more typical and efficiencies can be as poor as 15%. So, independent of the issue of simplex utilization, the telecommunications engineer for a satellite project should seek the most efficient RF transmitter design possible as a first-order design consideration.

The amount of power required to complete the data link is given by the system link analysis (or budget) and at a given data rate and for a given LEO orbit. That value is fixed once a minimum elevation angle for communications has been selected. If the reference orbit given above is used (600 km circular orbit) and if a typical UHF ground station is employed (13 dBi antenna gain and 425K system noise temperature), then at 437.5 MHz approximately 2 watts of RF power will be required to complete the link with 4 dB of link margin. [NOTE: For a small Earth station, a 4 dB link margin is not very much. A margin of 10 dB should be the design objective of a low cost ground station.] It has been assumed that the system has a 9600 bps data rate (using G3RUH FSK) and that a 10° minimum elevation angle must be supported. If the transmitter portion of the radio is 33% efficient and 2 watts of RF output is required, then the input power requirement is 6 watts DC. This implies that 4 watts of power are dissipated as heat during periods when the transmitter is ON.

For transmitter amplifier chains that have only modest efficiency and if data rates as high as 9600 bps must be sustained, it is clear that several watts of power must be dissipated by the transmitter when it is on the air. Since the satellite systems using this radio equipment are themselves very small, the transceiver must be highly miniaturized.

So the power density (measured in watts/cm²) in the vicinity of the amplifier chain is necessarily high.

A transmitter designed for terrestrial use can depend on three methods for the dissipation of the heat it generates:

- Convection: Heat transferred from the device to the air around it.
- Conduction: Heat transferred from the device to primary structure and then convected or radiated away.
- Radiation: Heat transferred from the device and converted into IR energy as a black body radiator.

If the same transmitter is to be used in space, dissipation via convection is no longer possible as all of the air goes away (unless some sort of pressure vessel is employed – an old Russian satellite thermal design trick).

[NOTE: To get a feel for this problem, take a 1 watt resistor of 4.7 ohms and place it across the leads of a current-limited power supply. Turn on the supply and limit the current to .45 amps. You should find the voltage is about 2.2 volts. This set of conditions will cause the resistor to dissipate approximately 1 watt. Wait a few minutes and carefully touch the resistor with your finger. You should find it's at least warm to the touch if not quite hot. If you were to repeat the exercise but, now place the resistor into a vacuum chamber (bell jar) and pump all of the air out, you would find the resistor would be very hot indeed and depending on the conductive nature of the leads used to connect the resistor within the vacuum chamber, the resistor might eventually fail. Now, what would happen if the current were increased to .90 amps (double the original value)? At this point the 1 watt resistor is dissipating 4 watts and in about the same volume of material as the 2 watt RF transmitter operating at 33% efficiency. The satellite designer must solve the problem of successfully dissipating this heat without destroying the transmitter and or the satellite. AND, this problem must be solved without using convection as a heat dissipation mode.]

The satellite system designer must determine:

- a) If the system can conduct the heat away from the transmitter and toward the radiating surfaces of the spacecraft sufficiently well so that the transmitter does not overheat during the ON period.
- b) If the system has sufficiently large surface area and sufficiently high thermal emittance properties so that the average temperature of the satellite is not exceeded during ON periods of the



transmitter. [Note that the thermal equilibrium temperature achieved passively by the satellite (and given by the radiance equation) depends upon the total surface area of the satellite and the thermal emittance of each surface. If the surface area of the satellite is very small then the equilibrium temperature can be quite high, especially if one has up to 4 watts of additional heat from the transmitter that must be dissipated.]

It is now appropriate to discuss the next set of issues related to the simplex operation of the system. The ON duration of the transmitter must be chosen. Several outcomes are possible:

- a) It may be that the ON duration of the transmitter is driven by the need to maintain the temperature at acceptable levels per the above discussion. This is bad, as will be pointed out shortly.
- b) It may be that the ON duration of the transmitter is driven by the need to maintain a positive energy balance for the spacecraft system.
- c) It may be that the ON duration of the transmitter is driven by the desire to transmit only during the time when the satellite is within range of the command station.
- d) Ideally, conditions b) and c) are mutually satisfied.

The above outcomes are in ascending order of desirability. If it is possible to maintain a positive energy balance for the satellite system by turning the transmitter ON only during periods when you can communicate with the spacecraft and IF it is possible to keep the transmitter on during the entire pass, this is the optimum outcome from both a technical and a frequency regulatory point of view. From a satellite security perspective, it may be desirable to turn ON the transmitter only when the satellite is in range of your ground station AND only for as long as it is necessary to download your data. In fact, it is worth noting here that other satellite systems licensed to transmit in other services are nearly always REQUIRED to keep their transmitters OFF except when in range of their respective ground stations. It is only in the Amateur Satellite Service that this is even an option. But, it is an option rapidly decreasing in popularity due to the rapid increase in satellite systems occupying Amateur Radio spectrum and the consequent need for them to share frequencies.

Failure Modes

Outcome (a) is particularly bad. If the transmitter can be turned ON only for very short periods so as to avoid overheating and if this process is continuous around each

orbit, a new failure mechanism arises. Not only are the transistor dies heating up when the transmitter is turned ON and OFF, but the bond wires are also rapidly heating up and they also quickly cool down. Since the bond wires are tiny and transport significant current and have very low thermal inertia, they heat and cool very rapidly. Like any piece of metal that is rapidly and repeatedly heated and cooled, the bond wires are subject to expansion/contraction stresses that can (and usually will) lead to a failure of one of the bond wires inside the transistor or integrated circuit. If plastic parts are used, the bond wires are embedded in a plastic material. It is often true that the thermal coefficient of expansion (TCE) of the bond wires and the plastic around them are quite different. If this is the case, the failure will occur all the sooner. So, the worst thing that can be done in this regard is to cycle the transmitter ON and OFF with a short period and with plastic parts which have a poor TCE match between the bond lead and the plastic.

The author learned this lesson the hard way. One mission, for which I had direct responsibility, used a VHF transmitter that had an ON duration of 30 seconds (which was long enough to download a long frame of data from the satellite instrument) and an OFF duration of 2 minutes (which was long enough to collect the data from the instrument for the next transmission period). The transmitter operated in this mode continuously. Despite the fact that this failure mode was anticipated prior to launch and that care was taken to fully heat sink the transistors in the power amplifier chain, the transmitter failed after about 1.5 years in orbit. The transmitter should have lasted for many years in orbit. It was not possible to prevent the thermal exercising of the bond wires.

The lesson here is to avoid rapid cycling of the transmitter unless you are certain that it is rated for this type of service. Minimize the total number of ON/OFF cycles for the mission. Turning ON and OFF the transmitter 6 to 8 times per day during passes is not a big problem. Turning the transmitter ON and OFF every two minutes, continuously around the orbit, every orbit of every day, to maintain thermal equilibrium is establishing a failure mode that cannot be avoided.

System Security

Secure operation of satellites has not been a first order design priority in the amateur-satellite service. There have been no known cases of anyone willfully commanding an amateur satellite without authorization and only a few cases where individuals have

attempted to interfere with another station's uplink signal. Where this has occurred, it has been related to signals associated with the normal communications function of the satellite and not the command or telemetry functions.

Still, some precautions have always been taken to avoid the temptation that may exist for someone else to commandeer a satellite. The standard precautions are:

- a) Never publish or in any other way cause to have known the command receiver frequency of the spacecraft. This should only be known by a very limited number of people within the project.
- b) Do not publish or reveal the details of the command system data and modulation formats.
- c) The spacecraft flight computer (or in a simpler case, the command decoder) should use some sort of password or ID (coded in hardware or firmware). This is to be done at the physical layer of the protocol.
- d) At a higher link layer in the software add some additional password-like security.

One might note that because of these precautions we probably wouldn't know if someone was trying to "hack" one of our spacecraft. It would be prudent to assume that regardless of the frequency or radio service, modulation technique or protocol, there are a finite number of people with the desire and capability to hack the satellite. The purpose of security techniques is to make it difficult for them to be successful usually by withholding the needed information.

In addition to the above precautions, many satellites have used fully uploadable software. The only unchangeable code is that used to do the uploading itself. The theory is that if a hacker does find the information needed to hack your satellite, one can upload new code with a different set of codes or a different protection technique. Most very small satellites do not have this capability so must have an "unhackable" command scheme that will protect it for the duration of the mission.

These precautions are quite simple and have always worked to date. Still, there has been much talk about using TCP/IP protocol to control satellite systems. Also, there has been considerable discussion about remote commanding using the Internet. Once a satellite system has been "connected" to the Internet and if the spacecraft employs standard data protocols, then clearly the satellite flight computer becomes an extension of the net. This action would open



up the satellite system to the entire world of hackers. Such thoughts might cause some rethinking of how important it is to protect amateur satellite systems.

Let's return to the radio frequency domain for it is here that the simplex system is most vulnerable. If someone wanted to directly tamper with a satellite's operation, there would be two ways to proceed:

- a) Obtain all of the information necessary to command the spacecraft and develop a system that operates on the command frequency used by the spacecraft and then transmit a valid command to the spacecraft, thus changing its state of operation.

OR

- b) Obtain knowledge of the satellite's command frequency. This could be obtained by anyone living or operating near the command station site since the emissions from the command station during routine commanding could be heard (detected, decoded, analyzed) from many kilometers away and in any direction from the command station via *ground wave*. Once the command frequency is known, the "bad guy" only needs to transmit a CW carrier toward the victim satellite at a power level (EIRP) adequate to interfere with that of the real commanding ground station. This is formally called a "denial of service" attack.

In case (a), the "bad guy" must work very hard because he has to implement all of the features the real command station has, including the security features. This is very difficult and there is little real motivation for someone to do this. Still, if someone were to do this, they would have the ability to cause maximum chaos up to and including the ability to "kill" the victim spacecraft. What prevents this from happening regularly is the lack of information necessary to accomplish it and the difficulty of obtaining that information.

In case (b), the "bad guy" only needs to detect the presence of your command link or know it because someone let it leak out. In addition, this person would need to know the orbital elements for the satellite. This set of information, available to all on the Internet, will allow him/her to know when the satellite is passing over the "bad guy's" ground station. By transmitting a simple carrier in the general direction of the victim satellite and at an adequately high EIRP level, the "bad guy" can *deny access* to the satellite by the real command station. If, at a particular time, a critical command was to be sent (such as one that turns a particular

subsystem ON or OFF for energy balance purposes), then by denying the real command station access to the satellite, damage to the satellite could occur - up to and possibly including causing the "death" of the satellite. NOTE: This is very easy for the "bad guy" to do. He needs only a little information to cause the victim very considerable potential grief.

A case (b) access denial event could occur at any time the real command station and the "bad guy" station are in mutual visibility of the satellite AND provided that the interferer's EIRP is higher. In effect, if the "bad guy's" location was within several hundred kilometers of the victim satellite's real command station, the interferer could prevent the spacecraft from being commanded by the real command station during virtually all of each pass. This situation is also somewhat difficult to recover from without another command station in another part of the world planned for in advance. Most small satellite programs have only one ground station. Quickly establishing another ground station outside the bad guy's footprint with all the needed capability is costly, time consuming and difficult. There may be licensing issues associated with the new station as well.

There is something else to be said about case (b). Many, if not most, command receivers used by the small satellite community employ frequency modulation (FM). FM receivers are cheap, non-critical to use and they are less prone to audio distortion due to an offset in frequency as could result from a Doppler-induced error in the command station's uplink frequency. FM systems, however, have one feature that helps the "bad guy" in our above scenario. FM receivers exhibit a phenomenon known as the *capture effect*. Let's assume two FM-modulated carriers are present and both are centered on the receiver's bandpass filter but that they are of different signal amplitudes. The receiver will enhance the signal-to-interference ratio of the stronger signal and reduce the signal-to-interference ratio of the weaker signal at the output of the FM demodulator. This behavior is quite nonlinear and is known as the capture effect. This effect is more pronounced for FM receivers that have a high modulation index (that is, they have a high deviation compared with the tone frequencies used to represent a "1" or a "0"). For a high-deviation FM receiver, the weaker signal may be virtually fully suppressed even if it is only 1 dB weaker than the "winning" signal. For low-deviation receivers (as may be found in the Amateur Radio service) the stronger signal might have to be 6-10 dB stronger than the

weaker signal but, if that condition is met, the weaker signal will simply disappear from the output of the receiver. This information thus allows quantification of how easy or hard it would be for an intentional interferer to overcome the desired command signal. By the way, having a signal 6 dB (a factor of 4) stronger than that used by the command station may not be a difficult task for the "bad guy" to accomplish. This can be done with a power amplifier device and/or a larger antenna.

Given the above set of explanations, the issue of simplex operation vs. security can now be discussed. It is clear that a case (b) scenario is far more likely than case (a). So much so, that case (a) can be ignored for purposes of these discussions. Let's assume that a simplex transceiver is used in the satellite such that the command channel is shared with the telemetry downlink channel. That is, the satellite might normally be in receive mode but, occasionally (upon command, via timer or under computer control) the receiver is turned OFF and **ON THE VERY SAME FREQUENCY** the transmitter is turned ON. If the "bad guy" knows *only* that the satellite is using a simplex system for telemetry and command, then it is already clear to him/her that the transmitter is broadcasting the command frequency. Now the "bad guy" is able to use a combination of automated and manual means to block the command frequency and deny access to the real command station and even the Doppler correction information is automatically provided to the interferer. This is a terrible scenario for satellite security! One could not possibly make it easier for an intentional interferer to be successful.

There is one variation on the pure simplex case that can occur and it is the next worst case. Sometimes the receiver is offset in frequency from the transmitter by a fixed amount. Standard Amateur Radio transceivers operating in the 144-148 MHz band, for instance, have a standard offset of 600 kHz (plus or minus, depending on the part of the band where operations occur). So, a "bad guy" would naturally look for the command frequency at 0 kHz, +600 kHz and -600 kHz from the transmit frequency in trying to jam the command frequency. There are standard offsets used in other frequency bands as well.

After these warnings, if it is still deemed appropriate to operate a simplex radio for telemetry/command, then the following practices can be recommended to provide some measure of security:

- a) Use a transmitter capable of using the highest reasonable output power and the highest practical gain antenna at the



satellite command station. This will give the command station the ability to generate a high EIRP and the largest link margin. This high power level should not be used unless it is strictly necessary to do so, but it will also help prevent an intentional interferer from capturing the command link. [NOTE: It is common practice in the amateur service and amateur-satellite service to use only the MINIMUM power necessary to maintain communications (and in some countries, including the United States, this is the law). However, it is also extremely important to be able to control the emissions from every satellite. Therefore, if intentional interference were to occur, it only seems prudent to be capable of generating a high EIRP in order to overcome a *denial of service* attempt. Such high power should only be used when necessary.]

- b) Use additional command stations located in other parts of the world. This is appropriate in any case but, such a strategy makes access denial much more difficult.
- c) Do not rapidly cycle between receive and transmit modes during any given pass. It is tempting to do this as the telemetry downlink could be used to acknowledge each command before the next command is sent. This is logical but is not in the interest of security. The “bad guy” can simply key his interfering transmitter based on detecting the trailing edge of the satellite’s telemetry signal (just as the satellite goes into the command receive mode). It is better to send commands at the beginning of the pass before the telemetry transmitter is turned ON and then verify that an entire batch of commands has been accepted. This, of course, means the command station must transmit to the satellite blind (i.e., without hearing the satellite at the time of acquisition-of-signal) and this requires operational confidence. Once one turns ON the telemetry transmitter, leave it on until the end of the pass (or until sufficient data has been collected) and make sure that there is a safe hardware or firmware timer that will eventually turn the transmitter OFF if the command station is denied access to the satellite. This will prevent the satellite from fully discharging the battery if the transmitter OFF command is not received. Notice that this recommendation is in keeping with the recommendation made in Section 2.2 above. That is, in general, do not cycle the transmitter ON and OFF rapidly.

Operationally, all of this is not very attractive. It’s much more likely the command station will want to first look at telemetry, then send some commands, and then once again, look at telemetry. However, a denial of service attack is likewise, undesirable. This is one more reason why simplex communications is a poor option.

- d) Do not use an FM receiver with a high modulation index UNLESS the command station being used can be sure of “winning” against an intentional interferer. Such a receiver “increases the stakes” in the access denial game.
- e) Do not tell anyone without a firm need to know about the details of your command system. The command receiver frequency is **THE** most sensitive of all pieces of information. By “details of the command system” it is meant ANY information about how it works. A potential bad guy can accumulate seemingly unimportant bits of information from a variety of sources and develop knowledge sufficient to attempt an attack. One of the fundamental precepts of this type of security is to make the job of interfering with your operation look so difficult that no one is tempted ever to try.
- f) Do not use a standard frequency offset (i.e., one common in amateur use) between the command receiver and the telemetry transmitter.

REGULATORY CONSIDERATIONS

This section has been left until last but, it is the most important set of reasons as to why serious consideration should be given as to how SIMPLEX operation is employed on any amateur satellite – indeed any satellite at all.

In principle, it must be agreed that simplex operation saves spectrum since two functions share the same radio channel. This is a very positive feature of simplex operation.

The problem lies with other regulatory considerations based upon failures similar to those in AMSAT operations discussed earlier.

Interference Control

Both national and international regulations governing ALL satellite operations in space require that transmissions from any spacecraft (amateur or otherwise) be under positive control at all times.⁴ A critical part of this control function is the ability to rapidly and effectively terminate some or all transmissions from your spacecraft.

It is not the intention of this paper to interpret the meaning of the words used in these regulations. That has been done elsewhere and will, no doubt, be done again in the future. However, it is a simple argument to make (and fundamental to the way radios work) that when the satellite’s receiver is OFF and its transmitter is ON, the command station cannot successfully command the satellite. In that literal sense, the command station does not have effective control of the spacecraft in the case of simplex operation. In simplex operation, when the transmitter is ON and the receiver is OFF, it is obvious that the system depends upon some form of timer or logical process to terminate the transmitter’s operation and return the command receiver to its “normal” state AFTER some event has occurred.

The failure of this mechanism leading to unintended transmitter emissions and uncontrollable interference is the root of the real regulatory concern.

There is a second part to this concern. Even if the transmitter and the receiver could operate separately and even if the receiver could be turned ON while the transmitter is transmitting and even if they did not share the same antenna and even if the transmitter and receiver were not on the SAME frequency (but, they were operating in the same frequency band), then IF the transmitter became “stuck” in the ON position, it is highly unlikely that the receiver could be accessed by the command station to turn OFF the transmitter. This is because the transmitter is so physically close to the receiver that it “overloads” the receiver front-end transistor devices. It is no exaggeration to say that the signal level reaching the command receiver input terminals from the on-board transmitter is typically on the order of 100 dB (that’s 10 orders of magnitude) stronger than a command signal arriving from the ground. If one was to attempt a filter design that would attenuate the transmitter at the receiver’s frequency say, 500 to 1000 kHz away, within the 435–438 MHz band and by an amount equal to 100 dB, it would be found that the filter is larger than the spacecraft (certainly larger than a “CubeSat”). So, the second concern is ANY type of satellite malfunction that causes the transmitter to become turned ON permanently and thus deny real access to the command system by the ground command station (even if the transmitter and receiver are separate but share the same frequency band).

In Section 2 above, it was noted that to successfully complete the downlink for a satellite in a circular reference orbit of 600



km altitude and at 9600 bps FSK it will require about 2 watts of RF power. That, in turn, implies a DC power requirement that could be as high as 6 watts (and is at best 3.5 watts) whenever the transmitter is ON. Certainly other functions on-board the spacecraft will require additional power. It is understood that very small satellites cannot sustain a positive energy budget if the transmitter is stuck ON. That means the satellite's battery will discharge. If careful attention has been given to the system design there will be protective hardware and/or software that will detect a battery low voltage condition and "shed" the major loads (i.e., turn them OFF). The "most major" of all such loads is surely the telemetry transmitter. If less care has been taken in the design, then the battery simply discharges and some logic states will change along the way and maybe the transmitter logic will reset as the batteries are discharged. This whole set of logical conditions may be modified by eclipse events that can occur on top of the battery discharge taking place, which was caused by the stuck transmitter. This is to say nothing about whatever the satellite experiments or payload may do to add to the set of logical conditions that must be considered. The question then is what happens next? If the satellite is designed to allow the battery to become fully charged before the major loads can be switched ON, then all could be fine. But, the question that must be asked is, under all possible logical combinations of conditions that could occur on-board the spacecraft, when power is restored, will the transmitter remain OFF until commanded to do otherwise? The key to all of this is very careful design consideration AND VERY THOROUGH FUNCTIONAL TESTING of the satellite in all of its modes prior to launch.

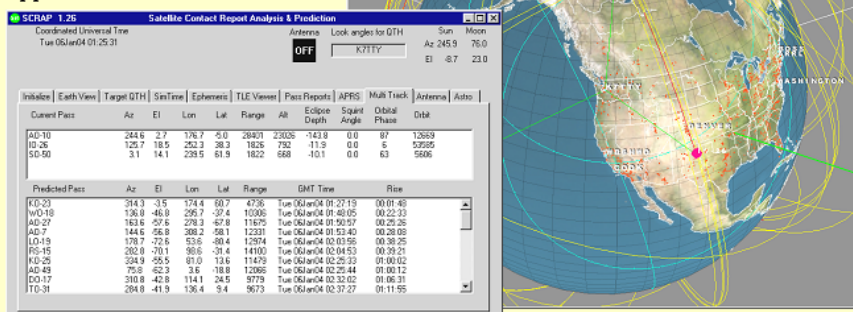
Recommendations to Enhance Compliance with the Radio Regulations

The following recommendations are made to those who still find simplex operation an imperative:

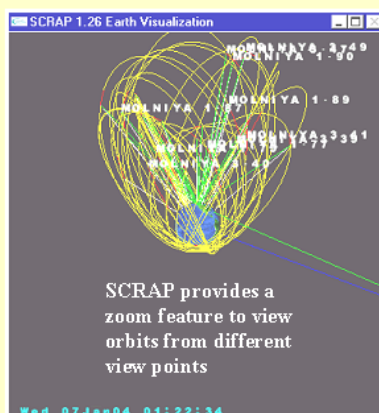
- a) Under no circumstances should a satellite be designed so that the transfer of a simplex radio system from its transmit mode to its receive mode is controlled only by a flight computer or a flight controller and its software (and most particularly software executed from RAM). If such control is executed by flight computer software and it is logically backed up by a hardware timer that could be OK. The most reliable way to control the transfer is by using a simple hardware timer/logic

Satellite Contact Report Analysis Prediction

AMSAT is now the North American distributor of SCRAP, a tracking program designed for ham satellite applications for Windows 95+

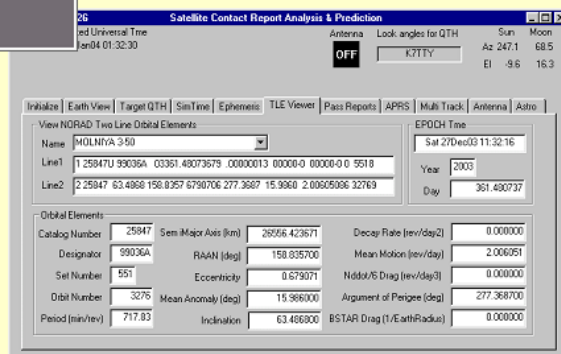


SCRAP provides a real-time contact report and display for over 2000 satellites on a Microsoft Windows 95+ Pentium platform.



Eleven panels provide for controlling functionality

1. Initialization
2. Earth View
3. Target QTH
4. Simulation
5. Ephemeris
6. TLE Viewer
7. Pass Reports
8. APRS display
9. Multi-Track display
10. Antenna rotor control
11. Astronomical prediction



SCRAP

is a product of the

Bytheway Software Development Lab (BSDL)

Price is \$50 for AMSAT members, \$60 for non-members, postpaid on CD-ROM. Order by calling 1-888-322-6728, or use the online shop at

<http://www.amsat.org>

The author, Bill Bytheway, K7TTY donated SCRAP to AMSAT. All proceeds support AMSAT.

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<http://www.rtty.com/bytheway>



solution ONLY. This is, admittedly the most conservative way.

Another solution would possibly be to place a second command receiver in another frequency band. This receiver could have, as its sole purpose, the resetting of the flight computer should it fail to perform the transfer from transmitter ON to transmitter OFF. Even placing the timer in firmware can be risky. Some FLASH ROM devices are radiation soft in the write mode. That is, they fail due to radiation damage (total cumulative dose) at low levels and the write function fails before the read function. This cannot be detected from the ground when it first occurs. So, if you were to write to the memory to change some function, the area of memory lost could be larger than the area being addressed. In this way, the firmware timer function could be lost. Certainly, not all FLASH RAM has this problem and by using FLASH known to be good for space, the designer could make this solution reliable. EPROM solutions are also bad, as EPROM is also prone to radiation problems. A controller/timer using radiation hard fusible-link ROM is a good solution. Also, an FPGA solution is good provided that the gate array is radiation tolerant.

- b) The spacecraft system design should assure that if the battery is ever discharged fully, for whatever reason, (but, most particularly because the transmitter was “stuck” ON) that after the flight battery has recharged and the system is ready for service again, the transmitter does not come ON again until it is commanded to do so. A good spacecraft system design will “gracefully” turn OFF all loads, starting with the transmitter so that the battery is never allowed to go completely flat (to 0 voltage). For many battery technologies, reaching such a low voltage state can cause what is known as *cell reversal*, and that condition is usually system-fatal.
- c) The spacecraft system design should assure that no combination of commands can cause the transmitter to become latched in the transmit mode, regardless of whether the system may recover once the battery discharges and then recharges. That is, one must not assume that battery discharge/recharge is the means of protection against a transmitter latch-up condition. A spacecraft known to work in this way should never be launched AND this would not satisfy the ITU Radio Regulations which require all

satellite transmitters to be under positive command control at all times.

- d) As a part of the spacecraft design process and as a part of the system level paperwork done for the project, the spacecraft should be thoroughly functionally tested to verify all of the modes of operation and all commands within each mode. Most particularly, it should be verified by test that no command sequence can be issued that will latch the transmitter ON and that after recovery from a battery under-voltage condition the spacecraft system returns to service with the command receiver ON and functional and with the transmitter OFF. Verification of this should be documented in a system LOG and it wouldn't be a bad idea if a letter were to be written for the file from the telecommunications engineer to the project manager verifying that these successfully completed tests were witnessed to occur. That letter should be signed by the telecommunications engineer and endorsed by the project manager. Thorough system level functional testing of the spacecraft is the most important recommendation the author can make. There are many space projects which have been launched by amateurs and professionals where testing has been abbreviated or eliminated due to the pressures of time. **THIS IS A BIG MISTAKE.** In almost every case, the project has lived to regret it. Murphy's law says, “If something can go wrong it will.” If you don't think this is a valid law, then you haven't built enough spacecraft yet. Don't test Murphy. Test the spacecraft so that design errors don't get into space.

THE RELATIVE RISK OF TX ON vs. TX OFF

Many will say they have heard this author say, “Never turn your transmitter OFF if you don't have to.” This is a true statement. It is difficult and sometimes impossible to figure out what is wrong with a “sick” spacecraft if the transmitter is not ON as any data is far better than no data. Even an unmodulated carrier from a spacecraft gives far more information than no signal at all.

It is also very difficult to command a spacecraft blindly and especially the very first time it “comes over the hill.” So, it is reasonable during the commissioning phase of a space mission to consider leaving the transmitter ON more of the time.

When using a simplex system, unfortunately, you are evoking the “unless you have to” clause associated with the

above little rule. From a regulatory standpoint and from a common sense standpoint it is important to have positive control. Spectrum is valuable and spectrum used for space is very valuable because of the surface area of the Earth covered by the satellite's transmissions. In many ways a simplex system works against the principle of positive control. Therefore, there is a consequence. The consequence is that you will most likely have to command the satellite without knowing where to point antennas and there will be some uncertainty regarding the AOS time for the spacecraft. This is particularly true in the first few days or weeks following launch, when definitive orbital elements for all objects placed into orbit have not yet been firmly established. Assuming that all of the above rules can be followed, it should still be possible to program the flight computer to turn ON transmitter just prior to AOS at the satellite ground station and then OFF some minutes later (say, just before LOS). So, all is not lost if that flexibility exists. The transmitter could be turned OFF a few times during a pass by program control to allow commanding but remember the “bad guy”!

A preferred telecommunication implementation for small space systems is a full duplex system that allows simultaneous command and telemetry transmission at will. There need not be any obvious relationship between the command frequency and the telemetry frequency. An alternative to turning the transmitter entirely OFF is to reduce its power (and data rate) so that at least some signal is present to track. Such an approach also reduces the potential for interference to others since the power level radiated by the satellite is lower and a lower data rate emission requires less bandwidth. This technique may require a larger ground station antenna system but then, that's a system trade you must make.

And, the subject of a low power beacon or telemetry link gets to the very last point. A part of the, “Never turn OFF the transmitter if you don't have to” rule also has to do with interference to others. A good reason for not keeping the transmitter ON when the satellite is not in view of the command station is the crowded state of the radio spectrum today. In the early days of amateur satellites everyone – everywhere – wanted to hear the very few (usually one) satellites that were available.

With the advent of the university satellite programs it has become an “every university for itself” kind of affair. So, one university's data are another university's interference. There are several cases where to coordinate the frequencies for two or more satellites,



the same frequency has been recommended. In such a case, successful coordination assumes that widely separated command sites will be used by these co-frequency projects and that the spacecraft transmitters will be used only in range of their respective ground stations.

So things are not as they used to be. Interference conditions now days dictate that satellite transmissions should be of short duration. Thus, it is no longer possible for everyone, everywhere to participate in the use of every satellite. For many of us this is an unfortunate state of affairs.

CONCLUSIONS

It must be acknowledged that there are several advantages to employing a simplex telecommunication design in very small satellites. However, the telecom link employed in a space system is not only critical to the operators of the system, but also to others who share the same frequency band. One must recall that the amateur satellite service is allowed in the 435-438 MHz frequency band only on a secondary basis. This means we must give way to other services that are primary services in the band. In the United States and in many other countries, this band is allocated on a "primary" basis to radiolocation (RADAR), usually for the government (military). If interference is caused to a primary service, we are compelled to cease all radio transmissions. This, in turn, means that it is absolutely imperative that each space system in the amateur-satellite service be capable of controlling its emissions. That burden is harder to confidently shoulder when a simplex system is used.

In addition to the regulatory imperative, there are other security and technical issues that have been raised in this paper. An effort has been made to point out solutions to these issues based on experience. It has been noted that the preferred solution is to employ a full duplex telecom system where data (commands and telemetry) may flow in both directions simultaneously and at the will of the command station operator.

Finally, it might be worth noting that, while flying a component designed for a terrestrial application appears attractive at first glance, after reviewing the modifications that must be made to the hardware and software for it to be flight worthy (both from a reliability AND a DESIGN point of view), it may turn out to have been wiser to design the unit "from scratch" to begin with. It's also true that you learn more by doing it that way. Unfortunately, this option is nearly always put aside as being too difficult, and the real problems of using terrestrial technologies in

space are frequently "swept under the carpet."

The author hopes this paper had provided some insight into the subject of simplex operation of small satellite systems.

APPENDIX - USEFUL TERMS DEFINED

Administration: Any governmental department or service responsible for discharging the obligations undertaken in the Constitution of the International Telecommunication Union, in the Convention of the International Telecommunication Union and in the Administrative Regulations. [CS 1002.]

Radiocommunication service: A service as defined in this Section involving the transmission, *emission* and/or reception of *radio waves* for specific *telecommunication* purposes. [RR 1.19.]

Simplex operation: Operating method in which transmission is made possible alternately in each direction of a *telecommunication* channel, for example, by means of manual *Control*⁵. [RR 1.125.]

Duplex operation: Operating method in which transmission is possible simultaneously in both directions of a *telecommunication* channel. [RR 1.126.]

Semi-duplex operation: A method that is *simplex operation* at one end of the circuit and *duplex operation* at the other. [RR 1.127.]

Amateur service: A *radiocommunication service* for the purpose of self-training, intercommunication and technical investigations carried out by amateurs, that is, by duly authorized persons interested in radio technique solely with a personal aim and without pecuniary interest. [RR 1.56.]

Amateur-satellite service: A *radiocommunication service* using *space stations* on *Earth satellites* for the same purposes as those of the *amateur service*. [RR 1.57.]

Station: One or more transmitters or receivers or a combination of transmitters and receivers, including the accessory equipment, necessary at one location for carrying on a *radiocommunication service*, or the *radio astronomy service*. Each station shall be classified by the service in which it operates permanently or temporarily. [RR 1.61.]

Terrestrial station: A *station* effecting *terrestrial radiocommunication*.

In these Regulations, unless otherwise stated, any *station* is a terrestrial station. [RR 1.62.]

Earth station: A *station* located either on the Earth's surface or within the major portion of the Earth's atmosphere and intended for communication:

– with one or more *space stations*; or

– with one or more *stations* of the same kind by means of one or more reflecting satellites or other objects in space. [RR 1.63.]

Space station: A *station* located on an object which is beyond, is intended to go beyond, or has been beyond, the major portion of the Earth's atmosphere. [RR 1.64.]

Telecommand: The use of *telecommunication* for the transmission of signals to initiate, modify or terminate functions of equipment at a distance. [RR 1.134.]

Space telecommand: The use of *radiocommunication* for the transmission of signals to a *space station* to initiate, modify or terminate functions of equipment on an associated space object, including the *space station*. [RR 1.135.]

Footnotes

1. With editorial assistance from: Tom Clark, W3IW1, Arthur Feller, W4ART, Graham Shirville, G3VZV, Ray Soifer, W2RS and Jim White, WD0E.
2. "Simplex operation: Operating method in which transmission is made possible alternately in each direction of a telecommunication channel, for example, by means of manual control." [RR 1.125]
3. Simplex operation may use either one or two frequencies. See the Appendix for definitions of related and other useful terms.
4. "Space stations shall be fitted with devices to ensure immediate cessation of their radio emissions by telecommand whenever such cessation is required under the provisions of these Regulations." [RR 22.1.]
5. 1.125.1, 1.126.1 and 1.127.1 In general, duplex operation and semi-duplex operation require two frequencies in radiocommunication; simplex operation may use either one or two. 🌐



PRESS RELEASE

Friday 30th, July 2004

New Amateur Satellite

Transponder Project Announced

The Chairman of AMSAT-UK, Professor Sir Martin Sweeting, G3YJO, today announced a new amateur transponder project to be launched as part of the ESA SSETI Express satellite.

Speaking at the opening of the 2004 AMSAT-UK Colloquium at the University of Surrey in Guildford, he expressed his delight that AMSAT-UK has been able to work with the European Space Agency to provide, at very short notice, an S band (2.4GHz) transmitter.



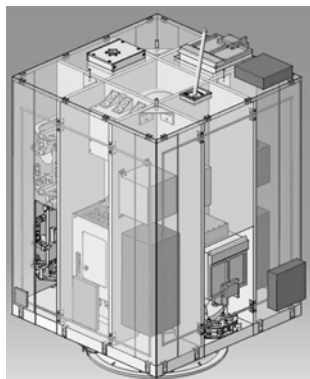
Professor Sir Martin Sweeting, G3YJO

The SSETI Express project is believed to be the first ever pan-European student satellite with over 100 students from more than nine different countries working on it. The project is being coordinated and managed by the Education Office of ESA.

It is intended that this transmitter will be available for use as the downlink of a single channel FM U/S transponder. The 437MHz receiver is also being provided to ESA by another radio amateur - Holger Eckart, DF2FQ.

These frequencies will enable the many amateurs who already have Oscar 40 equipment to use it in an exciting new way.

After integration of the spacecraft, which is



due to start at the ESTEC laboratories in the Netherlands next month (August), SSETI Express is intended to be launched into a sun synchronous 680km orbit from Plestok in Russia in April 2005.



The satellite is in the 80kg class and is being designed and constructed by a number of European university teams, which include students and teachers. The onboard experiments include attitude control, a camera and a cold gas propulsion unit.

It is intended that the 2.4GHz downlink transmitter will transmit satellite telemetry and data at 38k4 data rate before being switched over to voice transponder operation after the onboard experiments have been completed.

ESA will shortly be announcing a worldwide competition for radio amateurs who download the data from the satellite and forward it to a Web site which is under construction. There will be a valuable award for the amateur who provides the largest amount of verified data over the first few weeks/months of operation.

The 2.4GHz downlink exciter, the switched mode power supply and control interfaces are being developed by an AMSAT-UK team comprised of Sam Jewell, G4DDK, David Bowman, G0MRF and Jason Flynn, G7OLD, with Graham Shirville, G3VZV assisting.

The 3-watt, 2.4GHz power amplifier has been completed and was provided by Charles Suckling, G3WDG. This unit is already space qualified as it is identical to the one flying in the recently launched Oscar 51 spacecraft.

The S-band antennas are three flat plate patches that have been developed and produced by the Wroclaw University of Technology in Poland.

Professor Sir Martin Sweeting emphasised that AMSAT-UK is delighted to have been entrusted with such an important task and that development team will have the organisation's full support.

Those interested in finding out more about amateur satellites may like to know that AMSAT-UK produces an excellent newsletter called Oscar News, which is sent to all members. For further information contact the AMSAT-UK secretary Jim Heck, G3WGM.

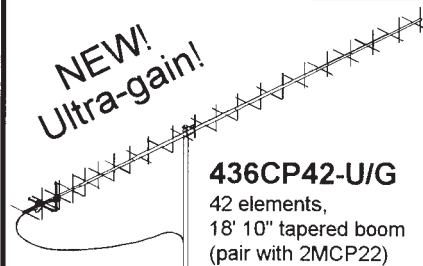
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E-mail: g3wgm@amsat.org

Website: www.uk.amsat.org

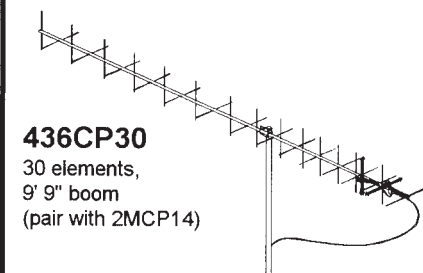
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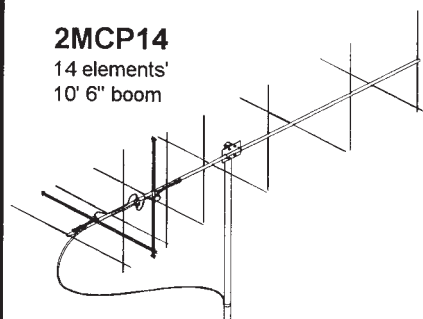
436CP42-U/G

42 elements,
18' 10" tapered boom
(pair with 2MCP22)



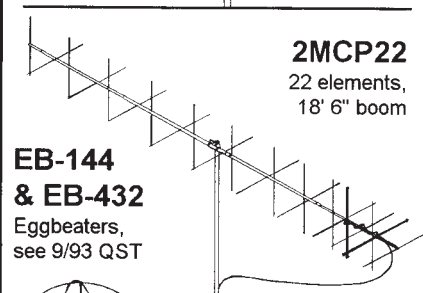
436CP30

30 elements,
9' 9" boom
(pair with 2MCP14)



2MCP14

14 elements'
10' 6" boom

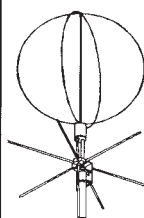


2MCP22

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Spread the Word

by Al Tribble, W3STW, AMSAT
East Coast Net Control,
wstw@juno.com

For over thirty years the students from the North East High Magnet School, in Philadelphia, Pa., have sponsored the SPARC Project. SPARC stands for Space Research Center. Students in this project come together to build and operate a simulation of the National Aeronautics and Space Administration (NASA) Space Shuttle Missions. The project is planned to impart knowledge in robotics, medical, engineering, computer science, flight planning, publicity, and secretarial work. A few physically and intellectually talented students are chosen to be Astronauts to operate the shuttle during the simulated flight. However, previous simulated missions were conducted without the Space Amateur Radio Experiment (SAREX) mainly because NASA's effort to involve Amateur Radio on the space shuttle was unknown to the students planning the simulated mission.

With the involvement of the Phil-Mont Mobile Radio Club (PMRC), the SPARC Mission planners were brought up to speed about the SAREX in a short 6-week crash program. Mission Specialist Alena Martinez-Hart received enough training, through a Technician Class taught by Al, W3STW, to become a candidate for a Technician FCC License and proved to be a successful candidate after being tested by Dusty, ND3Q, and his team. Media coverage of this year's Project Mission was provided by TV channel 29 serving the Philadelphia, Pa. area and can be viewed by pointing your browser to www.phil-mont.org web page and clicking on Fox 29 at the lower left of page.

All the students you see, in the video, possess a "B" grade as a minimum to be in the program. Jeswin is seated at the school's Amateur Radio station W3YC, the first high school in the country to receive a license from the FCC. ☺



Al, W3STW (l) and Dusty, ND3Q (r) with newly licensed Alena Martinez-Hart, KB3LDV.

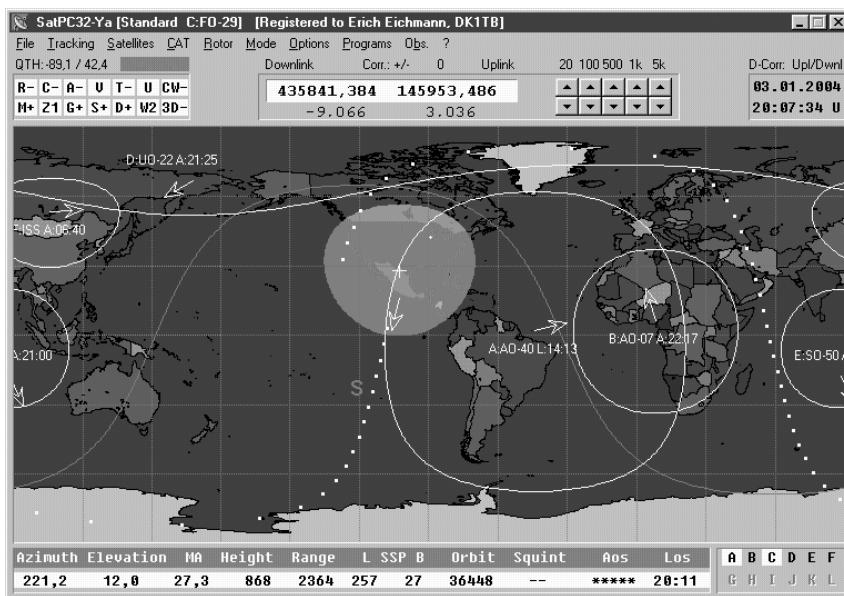
AMSAT is the North American distributor of **SatPC32**, a tracking program designed for ham satellite applications. For Windows 95, 98, NT, ME, 2000, XP.

Version 12.2 now supports Labjack U12 and W0LMD rotor controllers and Doppler tuning for Yaesu FT-817/857/897.

Features:

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- One-click satellite switching using 12 "letter" buttons.
- Automatic rotor control support for: Kansas City Tracker/Tuner, FODtrack, Uni_Trac, SatEL, Labjack U12/Piggyback, W0LMD Mini/Junior/Senior Trackers, Yaesu GS-232, ARS from EA4TX, EGIS rotors, IF-100, RIF-PC, AMSAT-DL interface, WinRotor32, HalloRotor, and WiSP DDE clients.
- Doppler tuning with on-screen frequency displays. Radio models supported:
Yaesu FT-847, FT-736R, FT-817, FT-857, FT-897
ICOM IC-820H, IC-821H, IC-910H and other ICOM radios
Kenwood TS-790 and TS-2000
DDE client programs
- "Transparent" VFO-knob tuning in addition to keyboard and mouse tuning.
- "Virtual" VFO tracking for half-duplex transceivers FT-817, FT-857, FT-897.
- Includes a special version for ISS split-frequency operation.
- Controls subaudible tone on FT-847, FT-736R, FT-817/857/897, and IC-910H.
- Includes a non-graphical version and programs that output lists to the screen, printer, or a file.
- Interfaces with WiSP, with user-defined satellite switching priority.

Price is \$45 for AMSAT members, \$50 for non-members, postpaid on CD-ROM.



Jeswin, KB3KOB is seated at the controls of W3YC.



Now that the AMSAT Online Store is in full operation, AMSAT is offering the ability to apply for and pay for any of the AMSAT Awards online.

To take advantage of this program, you need to scan your QSL cards (back only required if QSO info appears there) and send them as JPG or GIF files attached to your email. You may also put the images in a Word Document or an Adobe PDF document. Email your file to the AMSAT Awards Manager (presently, Bruce, KK5DO), kk5do@amsat.org and indicate which AMSAT Award you are applying for and your name as you want it to appear on the certificate.

After your application has been accepted and

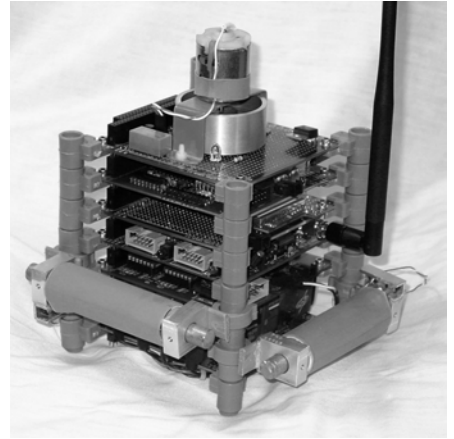
approved, you will receive a reply email instructing you to make your payment. You may then go to the AMSAT Online Store, <http://www.amsat.org> and make your payment. Your certificate will then be sent to you using the shipping address you used with the online payment.

Those without scanners may still send the Xerox copies of their QSL cards to the Awards Manager and then pay for the awards online after they are accepted.

For a list of all the awards that are available from AMSAT please visit <http://www.amsat.org> and click on Awards and Contests on the left menu.

Bruce Paige, KK5DO
AMSAT Awards Manager 🌐

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AMSAT Symposium 2004 Report

Gould Smith, WA4SXM, wa4sxm@amsat.org

Photos by Dick Daniels, W4PUJ

The 2004 Symposium in Arlington, VA, just outside Washington, D.C., proved to be a 'trifecta' for the 170 amateur satellite enthusiasts that attended. There were three informative meetings that AMSAT members could attend, the Symposium, the AMSAT board meeting held just before the Symposium and the ARISS meeting held just after the Symposium. The Crowne Plaza Hotel at Crystal City was the site for all three meetings. The Symposium committee, lead by Frank and Janet Bauer, had arranged good room rates at the hotel making it conducive to stay a few extra days - not only to attend the board and ARISS meetings, but to visit the Nation's capitol, just a short ride on the Metro's yellow line. The weather was ideal and the city was quiet during the Columbus Day holiday weekend. As usual the informal lunch, dinner and after hours gatherings with other AMSAT members from North America and abroad were as interesting and entertaining as the formal meetings and presentations. This was a wonderful weekend for all. If you couldn't attend this year make your plans for 2005 in Cajun country - Lafayette, LA.

AMSAT Board Meeting

The AMSAT board meeting began on Thursday morning, Oct 7, 2004 and consisted of four sessions Thursday and Friday morning. The experiment to have the board meeting precede the Symposium meant that the decisions made during the meeting could be announced during the Symposium, proved to be quite a success. Not only did Symposium participants find

out about the Board decisions, all AMSAT members will be able to read about the Board activities very soon. Steve Diggs, W4EPI, the new AMSAT Secretary, took notes and these will be published in *The AMSAT Journal* shortly after the Symposium. Previously the board meetings needed to be transcribed from audio to text, then would be edited and would finally appear months later. The early board meeting and the notes are good changes.

The board meeting got off to a rousing start with a complete reorganization of the AMSAT officers. AMSAT now has only nine officers:

President – Rick Hambly, W2GPS
 Executive V.P. – Lee McLamb, KU4OS
 V.P. Operations – Mike Kingery, KE4AZN
 V.P. Engineering – Stan Wood, WA4NFY
 Treasurer – Gunther Meisse, W8GSM
 Secretary – Steve Diggs, W4EPI
 Manager – Martha Saragovitz
 V.P. Marketing and User Services – Barry Baines, WD4ASW
 V.P. of Human Spaceflight – Frank Bauer, KA3HDO

These officers will make additional appointments over the next few months. The board went on to discuss the financial status of AMSAT, the budget, membership figures, fundraising, funding a feasibility study and electronic services. The operation of the on-line store generated a lively discussion before the lunch break. A short closed session of the Board followed lunch, then the meeting reopened for additional AMSAT issues. The discussion about the AMSAT Member Survey (published in the Sep/Oct

2004 issue of *The AMSAT Journal*) was next on the agenda with strategy proposals and the ANS report following. After the dinner break the Area Coordinator report was presented, the IARU report was made, the Dayton Hamvention report presented, the proposed AMSAT International meeting and Echo status were discussed. Friday morning saw a presentation about the ECHO launch campaign, a satellite testing proposal, Eagle report, Orbital Debris discussion, reports about conferences at AMSAT-DL and the Small Satellite Conference. The ARISS report was made and a budget discussion about Eagle ensued. I encourage all AMSAT members to attend the open board meetings to really experience what goes into the decisions that the board makes in the best interest of AMSAT.

The Symposium

The Symposium began Friday afternoon and went through Sunday at noon. Many of the talks for the symposium were sequenced by topic, making it easy to carry through a theme and reinforce important points. If you weren't there, I highly recommend that you get a copy of the 2004 Proceedings. It has invaluable and up to date information about many areas of amateur satellite activities. The first talks of the afternoon focused on the AMSAT Eagle project. Rick Hambly, W2GPS, lead off with a Fall 2004 Eagle Status Report. Dick Jansson, WD4FAB, discussed the Eagle project and showed drawings of the current spacecraft frame and its innovative power system. Steve Bible, N7HPR, talked about Eagle's hazardous radiation environment. The next session continued the Eagle theme with a fascinating spacecraft simulator program by Ken Hernandez, N2WWD, that allows modeling of the orbit and orbital changes. Ken has arranged with Braxton Technologies, Inc. to donate a couple of copies of the software to the Eagle team.

Tom Clark, W3IWI, expanded upon his C-C Rider concept from last year to place a C band (5 GHz) transponder on Eagle and challenged the engineering team to get that accomplished. Lessons learned from the AO-40 and AO-51 projects presented by Lee McLamb, KU4OS, showed the need for a thorough test procedure for Eagle.

The last session of the day had Gerald Youngblood, AC5OG, and Bob McGwier, N4HY, discussing the new features of the SDR-1000 Software Defined Radio. This technology will be integral to the Eagle



Rick Hambly, W2GPS, (standing right) the new AMSAT President, leads his first board meeting.





Some of the attendees at the AMSAT Symposium.

satellite. John Franke, WA4WDL, followed with a talk on how to make and use a bias tee in your satellite system. Some very interesting ideas and test data on screening your BBQ dishes to significantly reduce the background noise and improve S/N were presented by Tony Monteiro, AA2TX.

Poster Room

A number of well-done poster displays of university satellite projects, ARISS and the Hubble telescope were set up in the poster room. There were also quite a few pieces of hardware to examine like the ANDE and RAFT1 satellites and P-POD cubesat



Symposium attendees enjoy the "poster room".

launcher mechanism, Software Defined Radio and Voice/IP system. The contents of the room changed often and were well visited during the breaks.

Saturday Session

Echo was the morning session topic. The talks came in chronological order starting with a fascinating dialogue that tied the 2500 pictures that Chuck Green posted of Echo's last days on earth. Chuck didn't show all 2500 of course, but he did show a nice selection that told the story well. It turns out that getting the satellite to Baikonur may have been one of the more hazardous parts of the launch. Some interesting stories about his learning and experiences during the commissioning of Echo were told by Mike

Kingery, KE4AZN, an Echo command station.

Examples of how to operate the many available modes of the new AO-51 satellite were explained by Gould Smith, WA4SXM, using numerous screen shots. Sensor technology was explored by Alan Bloom, N1AL, and the morning session concluded with Peter Guelzow, DB2OS, talking about the AMSAT-DL P3E (HEO satellite) project and the P5A (Mars) mission.

Peter also announced that Arianespace, the Russian Space Agency and the IAF (International Astronautical Federation) are



Mike Kingery, KE4AZN, talks about his experiences as an AO-51 command station.

proposing to commemorate the 50th anniversary of the first satellite launch by orbiting a cluster of 50 nanosatellites in 2007, each representing a different country.

The afternoon session theme was ARISS operations. A panel of ARISS delegates from around the world lead off discussing issues, equipment and operations aboard the International Space Station. This was followed by two emotional (for the audience) talks about their school contacts with the ISS. One by Rita Wright, KC9CDL, and her eighth grade class in Burbank, IL. The other was by Carrie Cunningham,

N7NFX, and her group of third graders at Sonoran Sky Elementary, in Scottsdale, AZ. The technology of using Voice/IP with the ISS was presented by James Stefano, W2COP. James also demonstrated a VoIP contact with the current ISS team in the poster room during a break. There was an impromptu break during the morning session in which a radio contact with the ISS was made out in the plaza. The astronauts sent best wishes to the AMSAT Symposium participants and congratulated AMSAT on 35 years.

Graham Shirville, G3VZV, informed us about the SSETI Express student satellite project. This U/S mode satellite will take pictures of the earth and deploy three picosats.

During one of the breaks five of the past and current AMSAT presidents got together for a photo op.

The AMSAT Annual Meeting concluded the afternoon session. Rick introduced the new officers and talked about the new missions of AMSAT for educational outreach and to have three HEO satellites in orbit by 2012 giving 24-hour coverage. Two satellites produced by AMSAT-NA and the third by AMSAT-DL. The meeting was opened to



The current and four past presidents of AMSAT include (L-R): Bill Tynan, W3XO; Tom Clark, W3IWI; Perry Klein, W3PK (AMSAT's first president); Rick Hambly, W2GPS (new president); and Robin Haighton, VE3FRH (immediate past president).

questions from the floor to conclude the afternoon session.

Awards Program

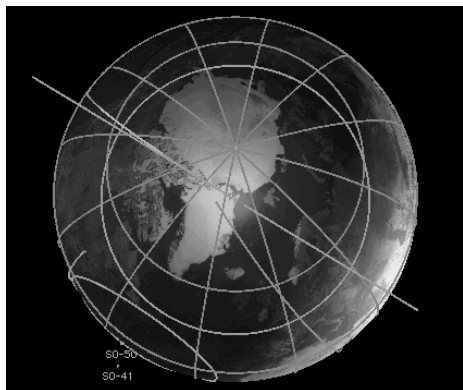
Another improvement from previous years was to have the Awards presentations Saturday afternoon during the AMSAT Annual Meeting rather than during the banquet.

A very nice silver, custom-made pin and certificate were presented to the following AMSAT volunteers and members in appreciation of their efforts for AMSAT:

Text continues on page 20 ...

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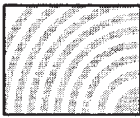
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See text on page 19, column 3, bottom.

President's Awards

Barry Baines, WD4ASW
Jan King, W3GEY
Keith Baker, KB1SF
Perry Klein, W3PK
Frank Bauer, KA3HDO
Dino Lorenzini, KC4YMG
Bob Carpenter, W3OTC
Lou McFadin, W4DID
Tom Clark, W3IWI
Stacey Mills, W4SM
Emily Clark, W0EEC
Bruce Paige, KK5DO
Ed Collins, N8NUY
Malcom Preston, N2PL
Dick Daniels, W4PUJ
Harold Price, NK0K

Steve Diggs, W4EPI
Keith Pugh, W5IU
Ken Ernandes, N2WWD
Martha Saragovitz
Arthur Feller, W4ART
Mike Seguin, N1JEZ
Bdale Garbee, KB0G
Ray Soifer, W2RS
Chuck Green, N0ADI
Russ Tillman, K5NRK
Rick Hambly, W2GPS
Bill Tynan, W3XO
Jim Heck, G3WGM
Roy Welch, W0SL
Bill Hook, W3QBC
Jim White, WD0E
Dick Jansson, WD4FAB
Paul Williamson, KB5MU
Lyle Johnson, KK7P
Terry Wittenberg, K0CEH
Mark Kanawati, N4TPY
Stan Wood, WA4NFY

Echo Project Awards

Dave Bern, W2LNX
Lou McFadin, W5DID
Tom Clark, W3IWI
Harold Price, NK6K
Bob Diersing, N5AHD
Doug Sinclair, VA3DNS
Chuck Green, N0ADI
Chuck Schultz, KE4NNF
Skip Hansen, WB6YMH
Graham Shirville, G3VZV
Lyle Johnson, KK7P
Charlie Suckling, G3WDG
Mark Kanawati, N4TPY

Jim White, WD0E
Dino Lorenzini, KC4YMG
Stan Wood, WA4NFY

Field Ops Awards

Richard Crow, N2SPI
Nancy Makley, KC8GYW
Steve Diggs, W4EPI
Dave Misek, N8NPX
Arthur Feller, W4ART
Chuck Pinkham, K3PER
Drew Glassbrenner, KO4MA
Gould Smith, WA4SXM

ARISS Program Awards

Tim Bosma, W6MU
Ken Nichols, KD3VK
Bill Boston, N3DCI
Kenneth Ransom, N5VHO
Gil Carman, WA5NOM
Dan Schultz, N8FGV
Lou McFadin, W5DID
Mark Steiner, K3MS
Robin Haighton, VE3FRH
Scott Stevens, N3ASA
Nick Lane, NC5KBO
Charlie Sufana, AJ9N
Will Marchant, KC6ROL
Dave Taylor, W8AAS
John Nickel, WD5EEV

Symposium Volunteer Awards

Janet L. Bauer
Rick Hambly, W2GPS
Elizabeth Clarke
Perry Klein, W3PK
Emily Clarke, W0EEC
Will Marchant, KC6ROL



The new officers of AMSAT-NA are (L-R): Steve Diggs, W4EPI, Corporate Secretary; Gunther Meisse, W8GSM, Treasurer; Lee McLamb, KU4OS, Executive VP; Mike Kingery, KE4AZN, VP of Operations; Rick Hambly, W2GPS, AMSAT President; Frank Bauer, KA3HDO, VP of Human Spaceflight; Barry Baines, WD4ASW, VP of Marketing and User Services.



Tom Clark, W3IWI
 Martha Saragovitz
 Dick Daniels, W4PJJ
 Dan Schultz, N8FGV
 Jackie Daniels
 John Shew, N4QQ
 Arthur Feller, W4ART
 Mark Steiner, K3MS
 Elaine Hambly, N3HWW
 Scott Stevens, N3ASA

ARISS International Delegate Recognition

Larry Agabekov, N2WW
 Ken Pulfer, VE3PU
 Frank H. Bauer, KA3HDO
 Sergey Samburov, RV3DR
 Gaston Bertels, ON4WF
 Masanobu Tsuji, JH2PRZ
 Joerg Hahn, DL3LUM
 Rosalie White, K1STO
 Robin Haighton, VE3FRH
 Alberto Zagni, I2KBD
 Keigo Komuro, JH1KAB

were all mode satellite radios an Icom IC-910H and a Yaesu FT-847.

Sunday Session

The AMSAT Area Coordinators started the morning with an early 6:45 AM meeting and breakfast. There were discussions about how to be more effective at hamfests and how the group can improve. New Area Coordinator Resource disks were handed out. Thanks to the work of Emily Clarke, W0EEC, the AC group will soon be able to update their AC information and download resources and presentations directly from the Web site.

Presentations began at 8:00 AM and ran until noon. Tim Salo, AB0DO, started the day with a presentation on the DoD Space Test program for free launches to space. Nick Pugh, K5QXJ, presented information about the startup of the University of Louisiana at Lafayette satellite program. Bob Bruninga, WB4APR, talked about the progress of the ANDE satellite at the Naval Academy,

symposium presentations. The buses were waiting to take about 100 participants to the new Air and Space Museum/Dulles Annex. The committee once again rose to the occasion and had arranged for guides to give us the grand tour. The museum was impressive with many classic planes from pre-WWI to today. Some of my favorites were the Space Shuttle, SR-51, Enola Gay and Concorde. The space section was not open yet, but we could walk up to the opening and see a number of the exhibits.

Monday/Tuesday ARISS Meeting

Frank Bauer arranged for the ARISS meeting to follow the AMSAT Symposium to provide an opportunity for additional people to meet the committee, find out more about the ARISS program and how they can contribute.

The committee is made up of an international contingent, with representatives from the US, Europe, Canada, Russia and Japan. School contacts obviously took up a good deal of the discussion. It was noted that it generally takes at least a year from the time an application is accepted until a contact with the ISS can be made. It is a challenge to keep the team of a teacher, principal and other supporters intact. They also discussed the new Columbus module and the 1.3 and 2.4 GHz antenna systems for amateur use.

'SuitSat'

Sergey Samburov, RV3DR, generated a great deal of excitement when he announced a new satellite possibility. With the limited number of flights to the ISS, trash is building up in the space station. Next year (2005) will be the 175th anniversary of the Bauman Moscow State Technical University, which is the alma mater for a large number of the



A variety of AMSAT members receive their President's Awards in this group photo.

Saturday Evening

The evening's activities began with the 'attitude adjustment hour', which is satellite jargon for a cash bar. AMSAT members and their guests filed into the banquet room at 7 PM and enjoyed a nice steak dinner. The speaker for the evening was Astronaut Carl Walz, KC5TIE, who related many stories of his four trips into space and showed some 'home movies' of life aboard the ISS. This year marks the 35th anniversary of AMSAT and the 30th anniversary of AMSAT-DL. There were two cakes to celebrate the anniversaries, one for each of the organizations. Rick and Peter did the honors and cut the cakes.

There were separate prize drawings for the AMSAT members and their guests. The program committee did an excellent job of collecting prizes and everyone came away with at least one prize. The two grand prizes

assisted by two cadets in the program. Bob teamed with Tony Monteiro, AA2TX, to explain an experimental space surveillance RADAR transponder for the RAFT1 cubesat. The University of Texas FASTRAC project using GPS for navigation was present by doctoral student Greg Holt, KE5BJC. Canadian doctoral student and veteran spacecraft builder Daniel Kekez, VA3KKZ, provided information about the spacecraft program at the University of Toronto and their new satellite CanX-2. To bring us back to earth Dan Schultz, N8FGV, expounded upon the enormous energy requirements to actually get satellites into orbit rather than just to the edge of space. Information about using natural vacuum electronics while in space was presented by Nickolaus Leggett, N3NL. Paul Shuch, N6TX, compressed his talk about winning the SETI Olympiad to conclude the



Sergey Samburov, RV3DR, discusses 'SuitSat'.





A great time was had by all at the banquet on Saturday evening.

engineers in the Russian space program. So, to solve a problem and to celebrate the anniversary, the Russians have conceived a plan to equip one of the obsolete Russian Orlan EVA suits with ham radio equipment (possibly a SSTV radio) and to 'launch' it into a very LEO in October 2005. Of course this was instantly dubbed 'SuitSat', and the engineers in the room began to formulate exciting ways to add features to this exotic spacecraft. Since the 'launch' is such a short time away and there is little available time for the cosmonauts to perform any tasks needed to convert the suit into a satellite, I am assuming it will be very simple satellite. But, there will be another launch opportunity for the second Orlan suit in 2007 to mark the 50th anniversary of the first satellite, so imaginations are quite active on how to equip this suit.

Bob Bruninga, never one to let moss grow under his feet, did some quick research during the lunch break and had a PowerPoint presentation ready for the afternoon session. He found out that OSCAR is the international symbol for 'man overboard'. He proposed that they dub the satellite RS OSCAR (Russian Satellite, Orbiting Suit Carrying Amateur Radio). He is a creative guy.

There were a number of additional issues discussed like licensing, third party agreements, hardware certification, the large number of additional modules required for testing to pass certification, labeling, and equipment configuration. With the large number of governments involved, each with

their own laws, seeming trivial matters require a great deal of discussion and compromise. A big Thank You to the ARISS team for volunteering their time to provide us with this great resource.

If you have never attended an AMSAT Symposium you are missing a wonderful experience. This is an excellent opportunity to become involved with AMSAT and to freely discuss your ideas and suggestions with the people that run the organization, design and build the satellites and control them after launch. I attended my first one in 1988 and mark it on my calendar every year. I have found the AMSAT Symposium to be one of the best experiences of my life. Don't pass up this opportunity to get to know some of the most interesting people you will ever meet. Attend the 2005 AMSAT Symposium!



Happy Holidays from The AMSAT Journal Staff!



Helical Antenna Tab Matching ...

... Continued from page 31

I cannot measure improvement on receive using the tab match. No apparent change from a "Shim Stock" antenna match was noted. I can match a Monofilar Axial-Mode helix to 50 ohms for transmitting. The phase relation between all the turns on my helical feeds are as close to being the same as I can physically space the turns, which is a physically measured value. The beginning of the helical first turn should be as close to the reflector as mechanically possible when using the tab match. All of the turns of the helix should have the same spacing including turn one for a Monofilar Axial-Mode helical feed antenna. "Shim Stock" matching was never as easy as the tab matching system. I have a notion that the "Shim Stock" match was made for folks without a return loss bridge. I suggest that it is much more difficult to adjust the VSWR when using the "Shim Stock" matching method.

Phase center location did not change. It remains approximately one turn from the reflector. I have not measured the axial ratio using tab matching. I had hoped to use the 1268 MHz tab matched feed on AO-40 mode L to provide insight (using QSB) into the circular polarization quality. Failure of AO-40 left that chore undone. I concluded that maintaining all of the Kraus coil parameters for the Monofilar Axial-Mode Helix and using the tab matching as Stan Wood has done on the AO-40 S2 antenna is an improvement over the "Shim Stock" matching method especially when using a helical for transmitting.

References

- [1] "Antennas" 2nd Edition, by John D. Kraus (W8JK) 



amsat.org

Echo's Versatility?

Check this week's configuration

See: Echo Control Team Schedule
on www.amsat.org

Wednesday is "experiment day"

Try it, you'll love it !

Field Ops Update: Celebrating Success and Moving Forward

Barry Baines, WD4ASW, wd4asw@amsat.org

One of the highlights of the AMSAT Symposium for me is the awards presentation. As I've noted in previous columns, I continue to be impressed by the number of people who "make the difference" in making AMSAT a successful and vibrant organization. AMSAT is blessed by both technical and managerial skills of our volunteers as well as the dedication of these individuals to use their time and talents to enhance our organization's ability to achieve our Vision and Mission.

This year the awards were presented at the Annual Meeting rather than at the Banquet. Another change was that recipients were recognized by group based upon the area of recognition (e.g. Field Ops, Engineering, Operations, etc.) and given their citation and a sterling silver AMSAT pin (designed and crafted by AMSAT member Gene Davies, AA6NP) without the reasons for the award being announced to the audience. While this certainly reduced the amount of time needed for the awards presentations, it deprived the audience of the opportunity to appreciate the significant contribution that each person made.

When we recognize the accomplishments of our award recipients, we also acknowledge the significant contributions of the entire Field Ops team. The value in recognizing individuals at the AMSAT Symposium is due in part to the opportunity to celebrate the overall accomplishments of the entire organization and to provide an inspiration for others to step forward to help AMSAT. What our volunteers achieve is extremely important to the future health of AMSAT, as we must continue to build awareness and support necessary to achieve our scientific and educational goals.

This year we recognized eight individuals under Field Operations who used a variety of skills to make a difference for AMSAT. These volunteers serve as outstanding examples of how to identify and fulfill a need by using their skills and enthusiasm that they bring to AMSAT. Given that we have not publicly proclaimed the significant contributions of our Field Ops recipients, here are the citations that were presented to these individuals:

Richard Crow, N2SPI: Once again you took the initiative to represent AMSAT at the Rochester Hamfest, one of the premier Amateur Radio shows on the East Coast which also serves as the ARRL Atlantic Division Convention. Your willingness to

drive a significant distance to represent AMSAT and to accomplish this with minimal support from other AMSAT members is indicative of the dedication that you have to AMSAT. Thank you for taking the lead to ensure AMSAT's visibility at this important amateur radio gathering.

Steve Diggs, W4EPI: Many thanks for your strong support of Field Operations in 2004. Once again you represented AMSAT at the Lawrenceville Hamfest this past November. In addition to assisting with setup and then manning the AMSAT booth at the 2004 Dayton Hamvention, you also provided satellite demonstrations that generated strong interest by newcomers to the hobby. You took the lead in representing AMSAT at the 2004 Atlanta Hamfest and made a presentation that was well received by attendees at the AMSAT Forum. You represented AMSAT at the 2004 Shelby Hamfest for the second consecutive year. Your enthusiasm and desire to represent AMSAT at these functions throughout the year are deeply appreciated.

Art Feller, W4ART: Many thanks for the graphics support that you provided to AMSAT this year. Your enthusiasm and creative thought resulted in the design of an AMSAT banner for display at the 2004 Dayton Hamvention as well as a 'Pigs in Space' t-shirt. You also took a lead role in designing various forms associated with our membership program to ensure the concept of 'premium membership' is a success. Your willingness to contribute your time and creative talent is appreciated.

Drew Glasbrenner, KO4MA: Thank you for stepping forward to fulfill several identified needs. Specifically, you put together an Echo fundraising program that provided guidance to our Area Coordinators on how to approach local clubs and organizations about supporting the Echo Launch Campaign. You also provided satellite demonstrations at the 2004 Dayton Hamvention and represented AMSAT at several hamfests. Finally, when Hurricane Charley severely damaged the facility where the AMSAT laboratory was located in Orlando, you took time to help relocate AMSAT laboratory equipment to a secure location. Your willingness to dedicate your time and talent to support AMSAT and newcomers is appreciated.

Nancy Makley, KC8GYW: Thank you for your active support of AMSAT's presence at the Dayton Hamvention. Over the past several years you have coordinated

reservations with AMSAT members attending Hamvention and served as an interface for the AMSAT dinner held on Friday evenings at the Amber Rose Restaurant in old North Dayton. This popular event has been well attended by as many as 90 people. Your work with the staff at the Amber Rose on food selection coupled with the desire to make the event affordable for our members brought enjoyment and good fellowship to those who attended the dinner each year. Your behind-the-scenes efforts are appreciated.

Dave Misek, N8NPX: Thank you for your active support of AMSAT's presence at the Dayton Hamvention. Over the past several years you have coordinated reservations in conjunction with the "Pizza 'n' Suds" event held on Thursday nights at Marion's Pizza in Beavercreek. This has become an annual event (2004 was the third year it was held) and has grown in popularity as a vehicle for making new acquaintances and renewing old friendships. It is only because you have taken the time to coordinate this event that it has become a regular feature. Your willingness to take on this responsibility is appreciated.

Chuck Pinkham, K3PER: Thank you for volunteering to assist with Dayton setup and takedown this year plus spending some time at the AMSAT booth. Your willingness to come to Dayton prior to Hamvention to help with the logistics of getting materials transported to Hara Arena and carried to the exhibit location was instrumental in ensuring a successful Hamvention for AMSAT. In addition, you spent an assigned shift at the booth during Hamvention assisting those who wished to make donations, join or renew their membership, etc. You also helped out as needed. Given that we were somewhat short handed, your willingness to step forward as a 'newcomer' is certainly appreciated.

Gould Smith, WA4SXM: AMSAT continues to be blessed with your outstanding support of AMSAT. Once again, you came forward with a new AMSAT publication *Echo: Operation, Development and Specifications* that met a significant need, generated additional enthusiasm and support for the Echo project and extended our educational offerings. Your work was thorough in preparation, easy to comprehend, and extremely informative. Your strong interest in helping others to enjoy our hobby is evident not only in your writing, but by how you've stepped forward to give presentations at the 2004 Dayton





Field Ops award recipients (L-R) Gould Smith, WA4SXM, Steve Diggs, W4EPI and Drew Glasbrenner, K04MA receive their AMSAT sterling silver pin and citation during the 2004 AMSAT Annual Meeting. Five other recipients were also recognized but were not available to attend the presentation: N2SPI, W4ART, KC8GYW, N8NPX, and K3PER. (Photo by Dick Daniels, W4PUJ)

Hamvention and the 2004 ARRL Kentucky State Convention in Louisville. You also supported our efforts to develop presentation materials for the Field Ops team. Thank you for sharing your extensive knowledge and enthusiasm for our hobby, which has helped others to become proficient as well.

Each of the eight recipients exhibited some common traits that are highlighted in each one of these citations:

- An AMSAT need was recognized by the individual;
- The individual figured out how to address that need;
- The individual dedicated their time and talent to handle the opportunity;
- Non-engineering skill sets were utilized to address the requirement (e.g. managing a process, creating teaching tools, working with newcomers, etc.);
- Typically, volunteers handled tasks outside their normal field of expertise (e.g. the treasurer volunteered to develop marketing programs while the Corporate Secretary took time to give satellite demonstrations and represent AMSAT at hamfests)
- In several cases, the recipients are not designated as Area Coordinators, but still fulfilled an important function and were recognized for their efforts.

Please take a moment to consider how you

can help AMSAT by utilizing your time and talents to address an AMSAT need. Think about using your skills that you may not necessarily use at work or handle a situation that requires skills that you'd like to develop. AMSAT is indeed 'US'—the membership. Each one of us has the potential to make a difference. Consider how your actions can reflect on AMSAT, such as giving demos, serving as an Elmer and working with local organizations to build support for AMSAT. Publicize the fact that you're an AMSAT member and that you welcome people's questions and interest in what AMSAT is doing. Unless we highlight AMSAT, we cannot assume that people will be aware of AMSAT.

Moving Forward - Enhanced Field Operations Support

Thanks to the efforts of Emily Clarke, W0EEC, we now have a significantly enhanced support site for Area Coordinators. The Field Ops Support System (FOSS) provides several new capabilities:

- Exchange of information (identifying specialty areas, such as familiarity with NOVA, digisats, etc.)
- Exchange of files (such as presentations and handouts)
- Tracking of upcoming events and activities (hamfests, club presentations, satellite demos, etc.)

Each active Area Coordinator now has the ability log into FOSS with a unique user name and password to update their personal information (such as e-mail addresses) so that any query sent from the AMSAT Web site to an area coordinator will go to the appropriate e-mail address. This new process will also greatly simplify the administration of Field Operations and ensure that an up-to-date listing of Area Coordinators is always available on the AMSAT website.

A new Event Calendar is now available within FOSS where Area Coordinators can list upcoming hamfests, club presentations, and other events that they are handling on behalf of AMSAT. This calendar will soon be available on the public portion of the AMSAT website. As Area Coordinators populate this page with future events, it should provide a great mechanism for knowing where AMSAT volunteers can be found at various events as well as document the extensive volunteer efforts of our Team.

FOSS also has the ability to allow Area Coordinators to upload and download support materials that can be shared with the entire Field Ops Team. This new process eliminates the need to produce and distribute the "Field Ops Toolkit" on CD-ROM and provides an effective medium for providing updated materials. For example, the Power Point presentation that I gave at the ARRL New England Convention at Boxboro, MA this past August has been further enhanced by WA4SXM and is available for download via FOSS by the Field Ops Team.

The 33 Area Coordinators who attended the annual Field Ops Breakfast early on Sunday morning of the Symposium were given an overview of FOSS by W0EEC. The breakfast also offered an opportunity to exchange ideas, discuss ways that Field Ops could support fundraising efforts for Eagle and other satellite projects, and encourage increased AMSAT membership. The Field Ops Breakfast has become an excellent vehicle for building team enthusiasm and encouraging our area coordinators to expand their support for AMSAT.

Many thanks to Emily, W0EEC for creating an outstanding tool that significantly enhances the ability of our Area Coordinators to serve as 'Ambassadors of AMSAT.'

Moving Forward - Organizational Change

During their October 7 meeting, the AMSAT Board of Directors created two new senior officer positions, including Vice President-Marketing and User Services that the BOD elected me to fulfill. I serve as a team leader

for a group of volunteers with responsibility for those areas that impact membership as well as deal with significant challenges such as fundraising. Marketing and User Services includes a new team leader for the Field Ops Team: Gould Smith, WA4SXM. Gould has made a significant contribution to AMSAT over the years by the extensive number of books and publications that he has authored and has been instrumental in serving as a mentor to those wishing to represent AMSAT at hamfests as well as encouraging newcomers to our hobby. His enthusiasm for sharing information and mentoring others plus his knowledge and ability to support and lead the Field Ops Team will benefit AMSAT greatly.

The Membership and User Services Team consists of the following individuals:

Director, *The AMSAT Journal*:
Ed Long, WA4SWJ

Director, AMSAT News Service:
Lee McLamb, KU4OS

Director of Contests and Awards:
Bruce Paige, KK5DO

Director of Electronic Communications:
Paul Williamson, KB5MU

Director of Field Operations:
Gould Smith, WA4SXM

Director of Web site:
Emily Clarke, W0EEC

Please do not hesitate to contact any of these team members should you have any questions or wish to share ideas pertaining to any of these areas. We continue to search for volunteers to support AMSAT in these functional areas as well.

With this change in leadership of the Field Ops Team, this is my last "Field Ops Update" column. Many thanks for your support of Field Operations over the past nine years that I have served as the team leader for Field Ops, and I look forward to working with you as the team leader for Marketing and User Services. 📡

Satellites via Repeaters

The SSPB Satellite Gateway Steve Forcht, VA3SF and Don Agro, VE3VRW

Introduction - VA3SF

I met Don, VE3VRW, a few years ago in early November 1995 when I was attempting to connect to the MIR packet station. I was sending packet connects to MIR, when over the radio on 145.850, I heard a voice telling me that Mir was over Australia and not North America.

After the appropriate introductions, I asked Don how he knew that Mir was over Australia and he told me that his software told him its location. I checked my software and asked Don how he knew that his tracking program was correct and mine was wrong. And he told me "Because I wrote it".

Don asked me to check my daylight savings time offset. This turned out to be incorrect in my program, Don told me his program automatically corrects for the time change. I was searching for Mir an hour before it was actually there. This began our friendship – and the seeds of the SSPB Satellite gateway.

The SSPB System

The concept for the VE3VRW Satellite Receive Gateway was born on a return trip from the Dayton Hamvention in 1997. As we were traveling through Detroit monitoring the V/U bands I heard white noise followed by a W1 station calling a W3 station. This was followed by a K6 calling the W1 station.

This sounded like a 20 meter DX pileup but was heard on VHF. Stations were calling other stations, giving their names and grid squares. I asked Don if he knew what that was and was told that it was the N8ULU gateway in Detroit who was down linking AO-27. My only knowledge of satellite operations had been working MIR on packet. Don proceeded to tell me all about AO-27 and his ability to operate it with his satellite station at home.

See: <http://www.geocities.com/semichamsat/amsat/gateway.html>

During the next 4 hours, we discussed how we could listen to the downlink of AO-27. By the time we arrived in Toronto, Don had devised a plan that

would allow the downlink to be retransmitted to the group of repeaters that I help sponsor in the Toronto and surrounding area.

The repeater group was known as the SSPB Amateur Radio Network and consisted of 7 repeaters located throughout Southern Ontario. The groups name is the first initial of the sponsors of the repeater group. These repeaters are linked 24/7 and all the facilities are open for all amateurs to use.

See: <http://members.rogers.com/va3sf/amateurprtr.htm>

Don told me that as he was quite busy with work projects, he would try to have it ready in a week or two.

The Gateway Opens

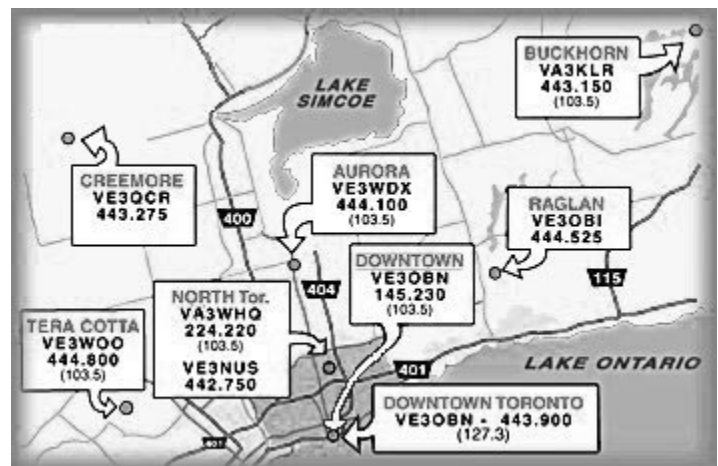
Much to my surprise, on my way down to work the next day, my mobile was suddenly overwhelmed by a white noise followed by the a rather busy pileup of stations from all over the U.S.A. Don had started down linking AO-27 to the repeaters.

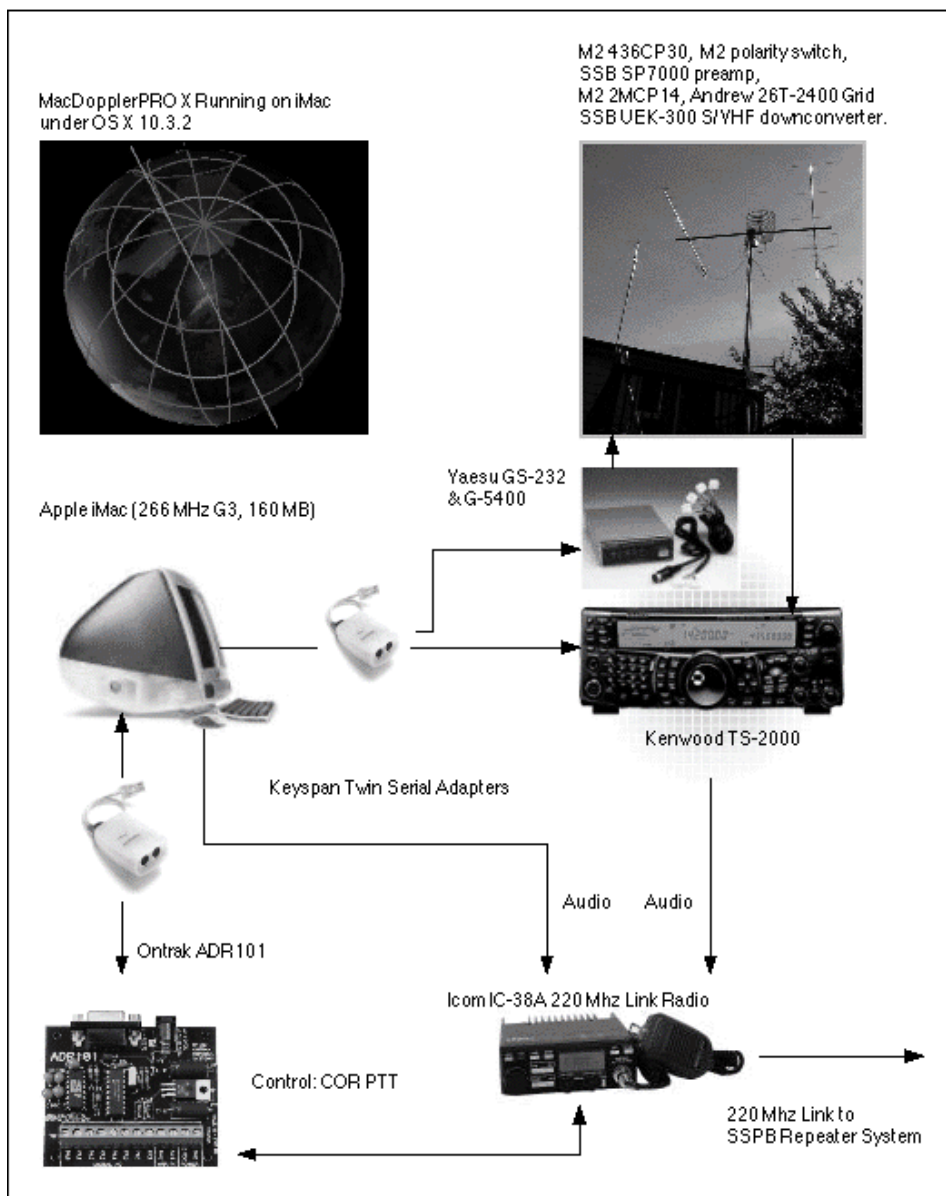
After the pass, the repeater became a question and answer session, with Don hosting the forum. Everyone was interested and curious to understand what we were listening to and eventually the discussion got around to how can we actually use AO-27. As hams, it's always nice to be able to listen, but we can listen to people on a scanner. We wanted to talk to these voices that we were listening to. Don told us that we would not be able to uplink through the repeater. He was concerned that a repeater uplink could too easily be abused either accidentally or otherwise.

As we had seven repeaters on different UHF frequencies there would not be a common uplink that Don could provide. The solution that we arrived at was that if Don provided the downlink on the repeaters, we could

Erratum

In the last issue of *The AMSAT Journal* Bernhard E. Keiser's e-mail address was listed incorrectly. It should have been w4sw@arrl.net. We apologize for the error.





uplink on the VHF uplink frequency directly. This of course was a manual switch by Don to provide this downlink.

The next day, I decided to try this. The downlink of AO-27 started and using my dual band mobile radio, I programmed the uplink frequency on the VHF side of the rig and proceeded to transmit. Squealing through the first transmission I quickly realized that I was actually listening to my self through the satellite. After adjusting my audio on the receive to stop the squeal, I made my first contact. With great excitement, I quickly exchanged location and grid squares with a number of stations. After the pass had finished Don manually terminated the transmission. Again the repeater became active with questions from a number of amateurs asking what they were listening to and how they could also talk to the satellite. This was the beginning of our

Satellite Gateway.

Unattended Operation

Over the next few months, the gateway was automated. Don had configured a COS circuit that would key up the radio linking into the repeaters and provide the downlink automatically to the repeaters at the proper pass time. There was also a built in timer that would reset the repeater timer every 1.45 seconds to allow the repeater controllers to ID and reset if needed.

Once we figured out how to work the satellite, we then had to be able to know the times of the passes. I used my tracking software to print out the times of the passes and would tell everyone on the repeater what these times were. I would check with Don, to make sure he would be home to be able to manually activate the gateway feed.

Amateur Paging

This worked for a while but was not the solution we were looking for. MacDoppler also has a voice announcement that tells the time of the passes. We could send this voice announcement, which was actually text, to a pager. The only problem was that we did not all have pagers. So, now we needed a paging transmitter and a way to tell the repeater users the satellite pass times.

We procured a 100 watt UHF transmitter and connected it through a packet node. We purchased ten pagers and re-crystaled them to a UHF simplex frequency. Now, when the satellite announcements are performed on the MacDoppler software, these same announcements are retransmitted to a pager in text messages carried by some repeater users. When a satellite pass was sent as a page, the information was then relayed to the repeater by one of the pager owners.

We used this method for about 6 months until one of the repeater users asked why the announcements were only available to a few operators who owned pagers. Also the users mentioned that they did not have any warning when the satellite gateway starting to retransmit a pass. A few feathers were ruffled when their local QSO's were interrupted with the sound of white noise.

See: <http://members.rogers.com/va3sf/paging.htm>

Voice Advisories

We discussed this problem and quickly realized that we did not need the pagers and could supply the audio from the computer running MacDoppler directly to the repeaters through the same link radio that was carrying the downlink audio. A few days later, the users of the repeater heard the voice of "Agnes", the voice of MacDoppler announcing the satellite passes.

Over the years since the inception of the gateway, we have refined the process and, using suggestions from users of the repeaters, have managed to provide the users with not only the satellite pass times, but with the maximum elevation and uplink frequencies.

Echolink Added

The SSPB group has two Echolink nodes running on the repeater system. The VA3SF-R node and the VE3OC-R node also run 24/7 and provide the VE3VRW Satellite Gateway to a worldwide group of amateurs. Many of them had never heard the downlink from a satellite. We now have hams from as far off as Australia, Thailand and Japan regularly listening to the satellite passes over North America.

There have also been number of hams in

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by Bob McGuier, N4HY, Gerald Youngblood, AC5OG and Eric Wachsmann
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North America that have discovered that if they listen to the pass via Echolink, they can uplink to the satellite via their 2 meter rig in the shack. The delay over the Internet is only about a second. This method provides hams with the ability to work the birds with just a 2-meter handy and an Internet connection.

This has opened up the Easysats to a larger number of hams. We have actually received e-mail from hams throughout North America who now have full blown satellite stations that started using the gateway via the Echolink nodes.

ISS

Now that ISS is occasionally in repeater mode, the challenge became how the SSPB users could work ISS. The usual method of

listening on the repeater and transmitting on VHF does not apply to the ISS repeater. We needed the ability to transmit and receive at the same time. It would be too easy to cause unintentional QRM by transmitting into the satellite without being able to hear yourself on the downlink.

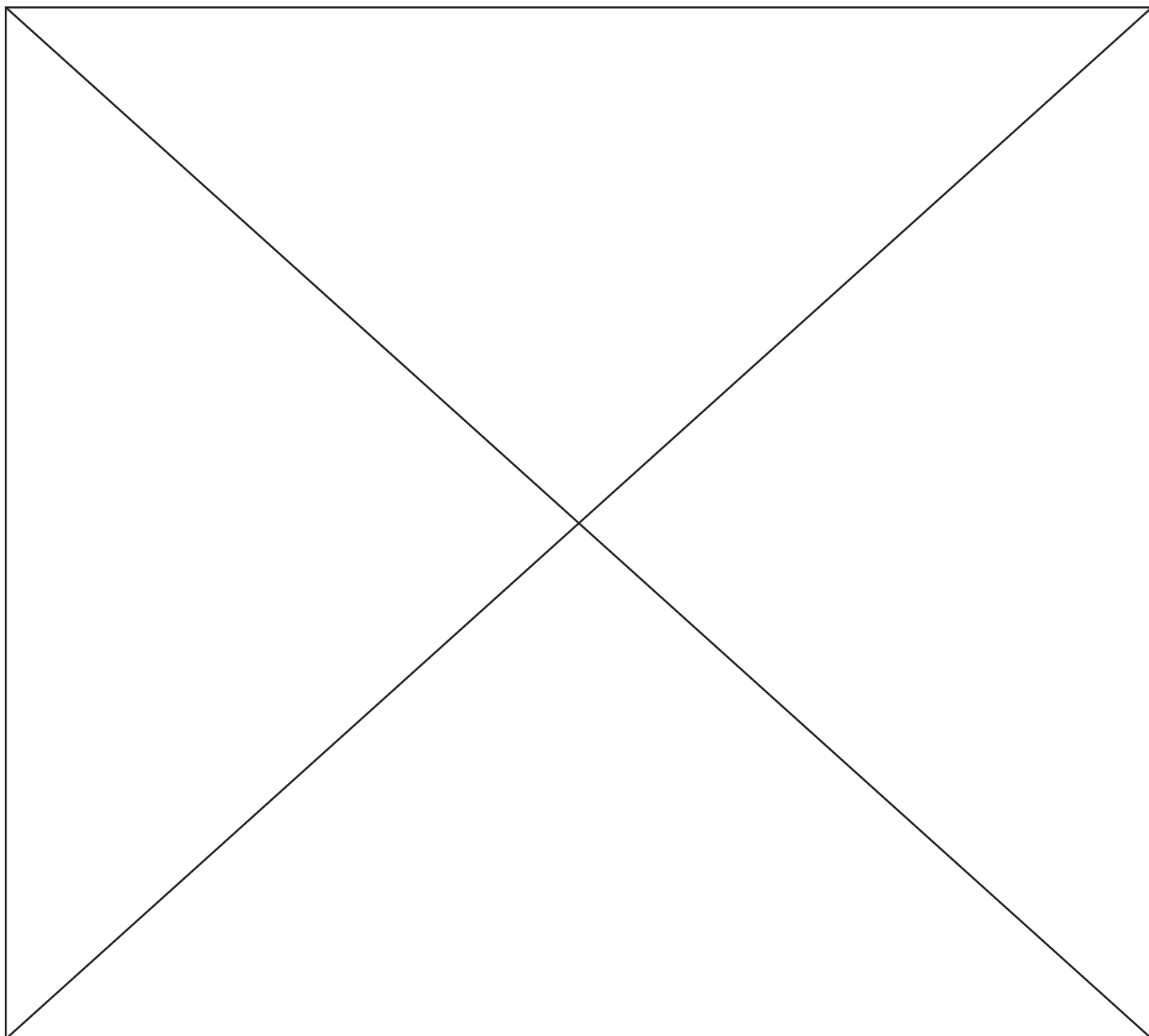
We linked a VHF repeater in a listen only mode connected into our repeater network. Now when ISS is overhead, the signals are transmitted from the UHF repeater system into a VHF repeater. So, we listen to the downlink on VHF and uplink to ISS on UHF simplex. Full duplex operation again, using the gateway as the downlink.

Over the past 8 years, we have been able to work the Easysats, talk to astronauts and

cosmonauts on Mir and ISS, copy SSTV pictures from Mir and provide help and guidance to many hams by giving talks and demonstrations at Amateur Radio clubs and flea markets. After every club demonstration, the next day, we hear a new call on one of the satellites and he is usually giving his grid square as FN03.

If you go to www.qsl.net/va3sf and click on the amateur page you will notice a small change. The SSPB Amateur Radio Network has recently been renamed to the SSPBD Amateur Radio Network. This added letter is out of appreciation for Don's hard work in providing a unique addition to amateur radio. It may be the only automated gateway like this in world.





The Gateway Today

Hundreds of Hams in Southern Ontario and Western New York have been using the VE3VRW Satellite Gateway via the SSPBD Repeater System to make contacts on AO-27, UO-14, Sunsat, SO-41, SO-50, Echo (AO-51), Mir and ISS since it was first installed in 1997.

See: <http://dogparksoftware.com/mdpxgateway.html>

MacDoppler PRO X automatically tracks up to 32 prioritized satellites 24 hours a day 7 days a week, completely unattended, controlling a Kenwood TS-2000 to correct for Doppler on all modes and pointing antennas through a Yaesu GS232 and G5400B combination.

Speech advisories are synthesized on the fly (rather than “canned”) with upcoming pass information, elevation and uplink frequency reminder, and are converted from ASCII text to speech and transmitted through the link radio on multiples of 60 minutes before AOS, 30 minutes, 15 minutes, 5 minutes and when the program switches to a new satellite. Daytime passes of AO-27 are skipped if they are known to be inoperative.

The functionality to run the gateway unattended has always been in MacDopplerPRO, but until version 2 depended on the hard-to-find ADBIO A/D converter while MacDopplerPRO X version 2.0 makes use of the Ontrak ADR101 to key the link radio PTT during passes and advisories and to “listen” to the COR to stop

satellite voice advisories from stepping on QSO’s in progress.

The “Control: COR PTT” line is actually 2 lines - 1 from the TS-2000 to put the link radio into transmit when there is either a synthesized voice advisory from the computer or the TS-2000 is receiving something (un-squelched).

The line from the (slightly modified) link radio to the ADR101 allows MacDopplerPRO to tell if the repeater system is busy (IC-38A un-squelched) and to wait until it is not busy before sending out the synthesized voice advisories.

All the logic to do this is included in MacDopplerPRO when the ‘Gateway’ option is selected. 🌐

A Visit to the James S. McDonnell Space Hanger

by Perry Klein, W3PK, w3pk@amsat.org

The James S. McDonnell Space Hangar opened Monday, Nov. 1 at the National Air and Space Museum's Udvar-Hazy Center near Dulles Airport. In it is a display case containing OSCAR 1, the U.S. Naval Academy's PCSat Thermal Mass Model, and NUSAT1. It's been many years since OSCAR 1 has been on display at the Smithsonian. It had been in storage in recent years at the Smithsonian's Garber storage facility in Suitland, Maryland.

Dick Daniels, W4PUJ, AMSAT's Archivist and I went out to the Udvar Hazy Space Hangar Tuesday, November 2 and took some pictures. A few are accompany this story. Below is the text of the signs accompanying the exhibit.

Amateur Satellites

Amateur satellites have been a small but important part of space activity since the beginning of the Space Age. In contrast to large-scale, expensive government

programs, amateur satellites demonstrate that the "little guy" can build working, useful satellites with commercial off-the-shelf components and small budgets.

Oscar I, the first amateur satellite, was launched in 1961 and inaugurated a series of communications satellites developed by the amateur radio community. Since that time, more than 40 Oscars (Orbiting Satellites Carrying Amateur Radio) have been launched. Amateur satellites have proven to be an ideal way to introduce college students to space technology. And as electronics have become more compact, powerful, and durable, amateur satellites have become an important way to demonstrate the potential of small spacecraft.

Oscar I Communications Satellite Full-Scale Model

Launched in December 1961, Oscar I was the world's first amateur satellite. The California-based radio operators who

developed the original built this model.

Gift of Project Oscar, Inc.
A19640011000

PCSat Thermal Mass Model

PCsat, developed by U.S. Naval Academy cadets and launched in 2001, allows amateur users to report and receive position information and messages from specially designed walkie-talkies nearly anywhere in the world.

Gift of the U.S. Naval Academy
A20040208000

NUSAT 1 Satellite

NUSAT 1 (Northern Utah Satellite) was the first student-organized satellite project. It was built by students at several Utah universities and flew on the Space Shuttle in 1985. This artifact is an engineering test model.

Gift of the Weber State College
A19870361000



Photo 1 - Display Case containing the OSCAR 1, PcSat and NUSAT. In the background is the Space Shuttle Columbia.



Photo 2 - OSCAR 1, including the satellite sign. Photo by Dick Daniels, W4PUJ

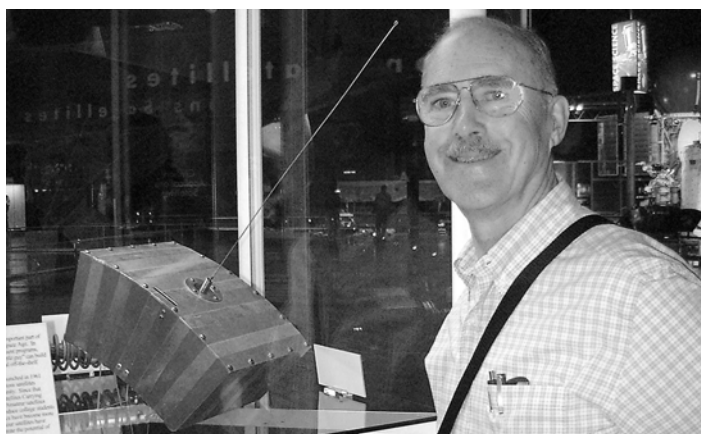


Photo 3 - Dick Daniels, W4PUJ with OSCAR 1. Photo by W3PK.

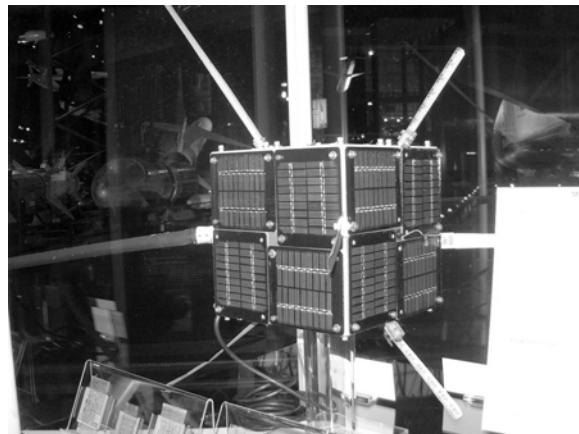


Photo 4 - PCSat with antennas and solar panels. Photo by W3PK.

Tab Matching the Monofilar Axial-Mode Helical Prime Feed Antenna (Useful for adjusting VSWR when using a helix for transmitting)

Joe Murray, K0VTY, k0vty@juno.com

AMSAT #860, AMSAT Area Coordinator, NE

For many years I have had concerns about how impedance matching of a Monofilar Axial-Mode 2.4 GHz helical prime feed antenna was done for my Mode S antennas. The matching method to which I refer is the familiar tapered shim stock fixed to the first 1/4 wavelength of the first turn next to the reflector. I'll call this method the "Shim Stock Matching" method. Lots of folks use it successfully, as have I.

Poor VSWR when using the helix for a prime feed antenna on 2.4 GHz receive will not cause havoc but may make the noise figure worse. However, poor VSWR when transmitting on mode L may burn up the RF amplifier. My desire to use a Monofilar Axial-Mode helix feed antenna for mode L and my desire to measure and adjust for improved VSWR caused a lot of work studying the matching of a helix feed to 50-ohm coax. Study of Kraus' [1] basic helix fundamentals provided that a raw (no reflector) Monofilar Axial-Mode helical requires something to make the wave proceed down the helix in the desired direction. Further, a raw helix exhibits an impedance of 140 to 150 ohms.

One of the referenced requirements of a raw Monofilar Axial-Mode helix is to have the same phase between all turns (turn spacing) of the helix. In Kraus, controlling beam width of a helix feed by changing the pitch is useful. Providing the wave launcher (reflector) and at the same time considering impedance matching to 50 ohm coax was the issue I needed to study.

The shim stock method of matching the helix to 50 ohms required that the first 1/4

wavelength of the first turn be bent so that the distance from the helical coil to the reflector no longer provided a constant phase (fixed turn spacing) between all turns. I suggest that this change in the turns spacing actually causes the helical action to begin at the end of that 1/4 wavelength matching section. If helical turn counting includes only those turns that exhibit the same phase, then the first 1/4 wavelength of the first turn would not be counted. If this is true then wave launching no longer occurs at the reflector. This method is described in my Kraus reference without however, any mention of my concerns. I wanted to know more about how a raw helix responds as the distance between the reflector and the beginning of the helix is reduced. I also wanted to know how any of this affected the phase center of the helix.

To further my investigation I constructed a 1268 MHz helix feed using a 3/16-inch thick brass reflector that was machined flat. The diameter of the reflector was 6.97 inches. The Monofilar Axial-Mode helix coil is made of #8 AWG (3.76mm) solid copper wire. The peripherally mounted N connector was modified to provide a rigid center pin 3/16 inches in diameter that would extend 1.25 inches above the surface of the reflector. This tall center pin allowed me to place the beginning of the helix over one turn from the reflector to begin my study of how the VSWR reacted as I reduced the spacing between the reflector and the helix.

The N connector center pin insulation is hard and provides lateral helix support by having a tight fit at the 3/16-inch thick reflector. The length of the pin allowed me to begin VSWR

measurement with the helix mounted at a distance greater than one turn of the helix from the reflector. Minimum pin length was used after the measurements were completed.

The VSWR measurements, as the distance from the helix to the reflector was incrementally decreased, indicated a slow steady linear reduction of

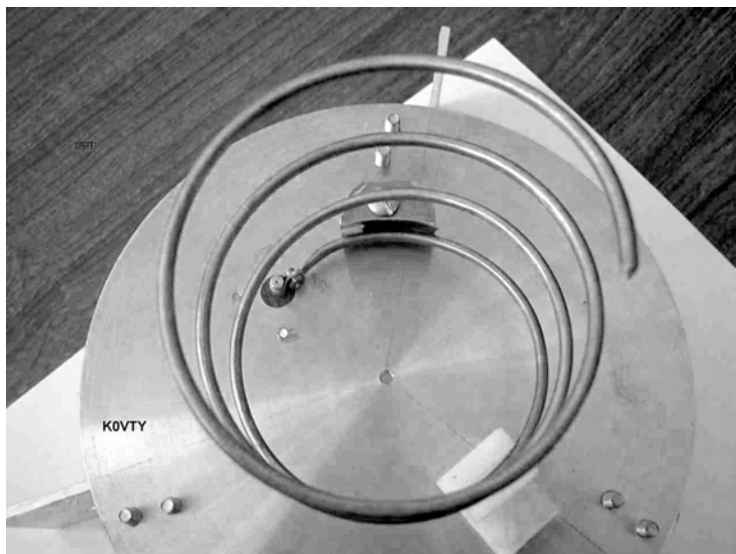
mismatch to 50 ohms. A 0.009-inch thick Teflon insulation sheet between the reflector surface and the beginning of the helix first turn provided insulation when the minimum distance between the coil and the reflector was reached. A reduced but still unacceptable mismatch remained. There was no impedance matching used at this point. The VSWR response with minimum coil/reflector spacing without matching was much less than 3:1.

Having seen a photo of the AO-40 S2 helix and what I considered its matching method to be, I devised a matching approach that I named "Tab Matching". I believe that Stan Wood is the designer of the AO-40, S2 helical antenna. My Kraus reference does not provide descriptions of helical tab matching. I do have an article indicating the use of a tab in a cavity backed helix antenna. The cavity backed helix article did not provide pictures or design information for cavity tab matching.

There are many differences between my tab matching approach, the approach used on the AO-40 S2 helix and the cavity back helix antenna. My first tab was a simple 1/2-inch wide piece of flat .05-inch thick copper sheet 1-1/2 inches long, bent in the center at 90 degrees. Holding the tab on the surface of the reflector near the beginning of the first helix turn I could apply RF and measure the VSWR as I moved the tab along the helix wire. Surprisingly there was very limited hand effect. I quickly found the singular sweet spot and began to move the tab either closer or farther away from the helix to improve the spacing between the coil and the reflector. The distance between the narrow 1/2-inch wide tab and the helix coil was considered too close for inclement weather conditions. The size (width) of the tab was increased to enable greater spacing between the helix coil and the tab. That improved the tab/coil separation. Then the wrap around tab shape shown in the picture and drawing was conceived to further increase the spacing between the tab and the coil.

Spacing between the tab and the helical coil good enough to survive inclement weather conditions was selected to be 1/8-inch or more. All of this work was done on the wooden workbench. The tab was wonderfully sensitive to adjustment without being too sensitive.

The response of the return loss bridge was



basically flat (25-30 dB) when the final tab size and shape was selected. A limit in return loss measurement imposed by the meter movement of 1-2 μ a was found acceptable for my purpose. It certainly is satisfactory for transmitting with a helical prime feed antenna on 1268 MHz.

The final tab dimensions for my 1268 MHz helix feed antenna were 1.5 inches wide by .75 inches high. Tab mounting to the reflector was accomplished with a #10-32 machine screw. The upper half of the 1.5-inch dimension is divided into approximately three equal sections (see template). The end sections are bent individually to form a curve that fits the curvature of the helical coil. Positioning of the tab is done as above until a location is found which will allow bending the copper tab into a final relationship with the helical coil to provide minimum VSWR. Final bending of the tab can be related to the end sectors alone or the entire tab keeping in mind that spacing is to be maximized between the coil and the tab. Mounting my feed antenna at the focal point of the dish provided no changes in the return loss. This is because LHCP reflects RHCP off the dish surface. The RHCP reflection does not effect the VSWR of the LHCP feed if the feed is properly positioned.

A transmitting amplifier was planned for the rear of the dish. This made necessary the use of 6 feet of hard line (HL) from the feed to the amp. After installing the HL a slight change in return loss was noted at the amplifier end of the HL. A very slight tab adjustment returned the loss to flat. The

return loss bridge I use is a single band unit purchased from SatEl, Brentwood Ca. I have two units, one for 1.2 GHz and the other for 2.4 GHz. The more important measurement issue is the sensitivity of the analog meter movement being used with the bridge. I am using a 16 μ a full scale on a 6-inch meter and what I call flat is a 1-2 μ a reading.

The only other tab related issue involves the focal point mounting where the helix feed should be mounted so that the tab is on the side of the helix so that rain will not puddle between the helix coil and the tab.

I have, since building the transmitting helix feed, transferred the tab matching method to a AO-40, 2.4 GHz, prime helical dish feed for receive. It worked fine on receive. At least I cannot measure any difference between the tab match and the shim stock matching system feeding a Kuhne preamp.

The procedure I followed to impedance match my Monofilar Axial-Mode helix with my tab match is as follows:

An instrument(s) that measures VSWR as the tab is correctly positioned adjacent to the helix coil is required to correctly use tab matching. There are several instruments that are capable of providing the required VSWR measurement. I used the SatEl return loss bridge (RLB). (Note: I have no connection to the SatEl organization.) Positioning the tab is very simple if the SatEl 1.2 GHz Bridge is available. The SatEl unit I used provided the 1.2 GHz RF signal, the RLB and the external 50-ohm load reference. The SatEl RLB does not have a display. A very sensitive analog meter is required. I used a Simpson Model 269 multimeter. This is a

100,000 ohms per volt voltmeter. There is no adjustment required of the SatEl unit. It is battery operated and portable.

Fasten the helix to be matched to a wooden bench with the radiating end of the helix pointed up. Place the 90-degree tab on the reflector surface so that by using a finger it can be retained and moved to a location of 50-ohm impedance match.

Locate the tab near the connector where the helical coil beginning is fastened. The tab is not allowed to touch the helical coil at any

time during this procedure. As the tab is moved along the helical coil the VSWR indicator provides easy indication for locating the tab. Once the approximate tab location has been found, additional effort should be made to ensure the distance between the coil and the tab is maximized. The distance between the coil and the tab should be the same on both ends of the tab.

Mark the reflector for drilling by using the tab mounting hole to draw a circle. This is not the real machine screw hole location however. The tab must be moved further away from the coil so that the tab sections can be bent to improve the VSWR.

Remove the tab and place a centering mark in the previously made circle. The real drill hole is 1/16 inch further away from the coil. Move the centering dot 1/16 inch further away from the coil and drill a hole for a #10-32, brass machine screw. Attach the tab to the reflector maintaining an equal distance between each end of the tab and the coil. The tab must now be bent with the top of the tab toward the coil to return to the previously measured VSWR. After the minimum VSWR has been obtained, additional VSWR improvement can be made by bending one end of the tab toward the coil, then the other end. Bending the tab ends in this manner makes the tab form to the shape of the coil. This process can be followed until no improvement in the VSWR can be obtained. My results provided 1-2 μ a on a 16 μ a full scale meter movement, which is not much current flowing.

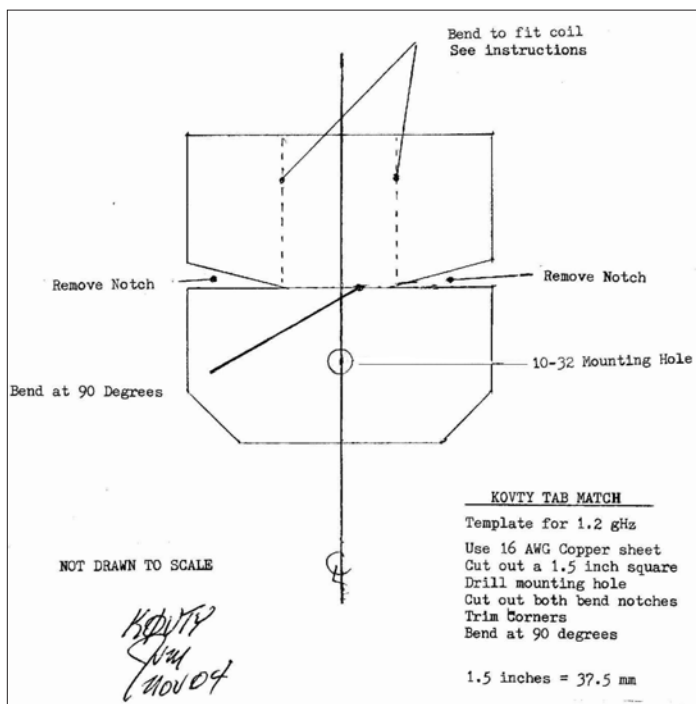
Summary

The tab height should be limited to one half the helix turn spacing. The tab must be as small as possible and at the same time the tab must be large enough to cause the spacing between the tab and the coil to be at least 1/8 inch and still provide a match to 50 ohms impedance.

My Monofilar Axial-Mode helical prime feed antenna has three things that are basically different than my tapered shim stock feed antenna.

1. The raw Monofilar Axial-mode helical coil maintains equal spacing between all turns including turn one.
2. A tab matching system is utilized in place of the familiar tapered shim stock to keep that first turn spacing the same as all the other helix turns.
3. This I believe keeps the wave launching at the reflector surface as compared to how the "Shim Stock" method launches waves as discussed above.

Text continues on page 22



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